THE NEIGHBORHOOD ALCOHOL ENVIRONMENT & PEDESTRIAN INJURY RISK: A SPATIAL ANALYSIS OF PEDESTRIAN INJURY IN BALTIMORE CITY

by
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ABSTRACT

Overview: Excessive alcohol consumption is a leading contributor to pedestrian injury, yet consumption patterns alone do not account for increased pedestrian injury rates in communities where alcohol outlets are located. The overall goal of this research study was to find new strategies to reduce alcohol-related pedestrian injury in Baltimore City. This study aimed to (1) Describe the prevalence and distribution of pedestrian injury in Baltimore City; (2) Address the lack of a comprehensive database cataloging traffic safety infrastructure in Baltimore City; and (3) Investigate the impact of the neighborhood presence of alcohol outlets on pedestrian injury.

Methods: Data included pedestrian injury EMS records from January 1, 2014, to April 15, 2015 (n=858), off-premise alcohol outlet locations for 2014 (n=693), and neighborhood disorder indicators and demographics. Pedestrian injury rates by age group, gender, and race were compared to national rates. Locations of pedestrian injuries and alcohol outlets were geocoded and mapped. A novel environmental observation assessment tool was created and validated to capture pedestrian safety infrastructure. Negative binomial regression models were used to determine the relationship between alcohol outlet count and pedestrian injuries, controlling for other neighborhood factors. Spatial correlation was assessed and regression inference adjusted accordingly.

Results: The overall rate of pedestrian injury was twice the national rate, and rate of childhood injury was five times the national rate. The distribution of pedestrian injuries throughout the city did not coincide with population or income distributions. Each one-unit increase in the number of alcohol outlets was associated with a 19.3% (95% CI=(1.146, 1.245)) increase in the relative risk of neighborhood pedestrian injury, adjusting for traffic volume, population density, percent of vacant housing, and median household income. The attributable risk was 18.8% (95% CI=(16.1, 21.5)) or 155 extra injuries. Vacant housing was the only significant neighborhood disorder indicator in the final adjusted model (RR=1.023, 95%CI=(1.014, 1.032)).

Conclusion: This study reinforces the importance of alcohol outlets in understanding neighborhood pedestrian injury risk, identifies new risk factors for pedestrian injury previously unexplored in the literature, and provides important public health evidence for informing policy decisions about liquor store licensing, zoning, and enforcement.

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CHAPTER 1. INTRODUCTION

BACKGROUND

In 2014, 4,884 pedestrians were killed and approximately 65,000 were injured by motor vehicles nationwide, and almost 80% of pedestrian fatalities occurred in urban areas (National Center for Statistics and Analysis, 2016). Pedestrian fatalities nationwide have increased over the last five years (National Center for Statistics and Analysis, 2016). Studies examining this increase have been focused at the national level, and localized studies of pedestrian injury have been scarce. Data on national trends in pedestrian injury are useful for focusing research questions and identifying risk groups for directed inquiry; however, they may incorrectly characterize risk factors unique to specific metropolitan areas. Because of the diversity of urban landscapes across the country, understanding injury trends at the local level is essential for program planning, allocation of funds for urban planning and improvement, and targeted injury prevention efforts. Considering the variety of urban landscapes, coupled with the unique safety challenges posed by urban sprawl and the growing popularity of mixed-use land developments, localized strategies to increase pedestrian safety are particularly relevant (Ewing et al., 2003; Miranda-Moreno et al., 2011; Stevenson et al., 2016).

Alcohol is an important risk factor for pedestrian injury on two levels. First, those under the influence of alcohol are at increased risk of being both the perpetrators and victims of pedestrian injury and fatality (National Center for Statistics and Analysis, 2016). Excessive alcohol consumption is a leading contributor to pedestrian injury and fatality in the United States. Alcohol consumption was involved in 48% of motor vehicle crashes that resulted in pedestrian fatalities in 2014; of the pedestrians involved in fatal crashes, 34% had blood alcohol concentration (BAC) of 0.08 g/dL or higher, while only 14% of drivers involved in these crashes had BAC of 0.08 g/dL or higher (National Center for Statistics and Analysis, 2016).

Second, more pedestrian injuries occur in areas with greater concentrations of alcohol outlets (Escobedo & Ortiz, 2002; LaScala et al., 2000, 2001; Schuurman et al., 2009; Treno et al., 2007). A New York City study found that the presence of at least one alcohol outlet in a census tract increased the relative risk of alcohol-involved pedestrian or bicycle injury by 47% (DiMaggio et al., 2016). Another study of four California communities with populations over 150,000 found that alcohol-involved pedestrian crashes occurred more frequently in areas with greater bar density (LaScala et al., 2001).

Few studies have examined the impact of alcohol outlets on pedestrian injury risk above and beyond that attributable to intoxication, and no studies have examined this relationship independent of intoxication. The occurrence of pedestrian injuries around alcohol outlets may be a result of the diverse social and physical characteristics of the community in which the injuries occur (Gruenewald, 2007; Toomey et al., 2012; Treno et al., 2007). Little research exists which conceptualizes the mechanisms by which alcohol outlets impact pedestrian injury risk.

Although the current literature on pedestrian injury includes research on a variety of individual and environmental risk factors, few studies have examined neighborhood factors with specific geographic components which can be generalized to other communities (LaScala et al., 2004). Examining the geographic distribution and impact of neighborhood and community features on pedestrian injury risk, in addition to identifying unique local risk factors, may lead to generalizable policy recommendations and more effective interventions to reduce injuries (LaScala et al., 2004). This dissertation examines characteristics of the local population and the local pedestrian environment, as well as specific neighborhood and geographic features which influence pedestrian safety.

STUDY RATIONALE

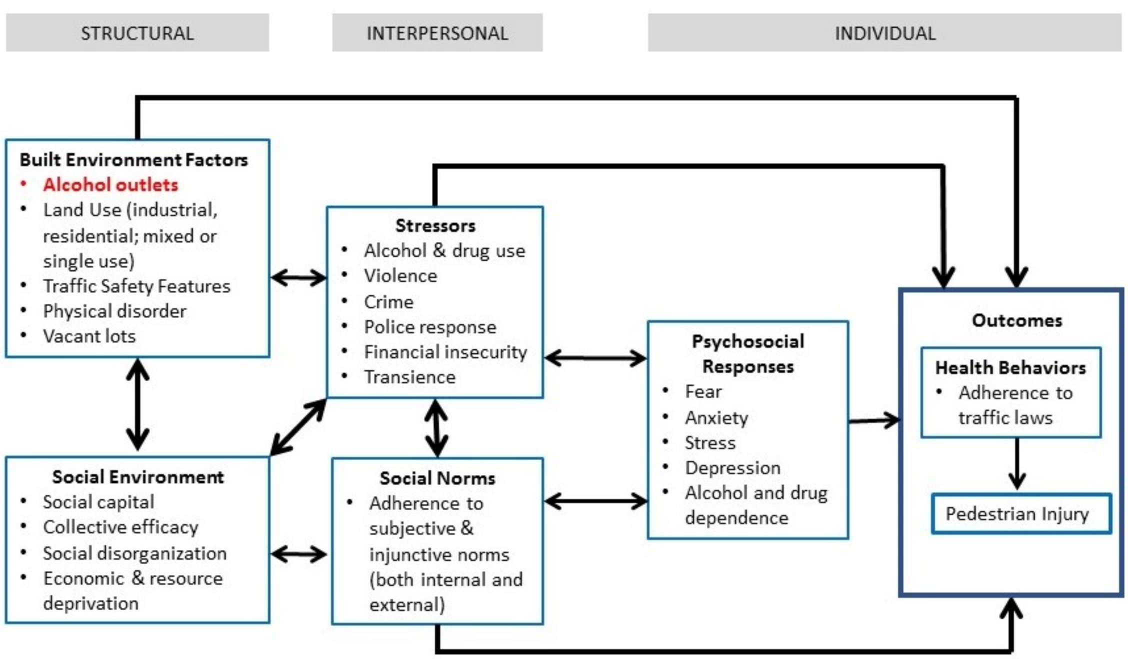
The overall goal of this research study is to understand the influence of neighborhood alcohol outlets on unintentional injury risk, increasing the evidence in support of alcohol outlet reduction. A significant body of research has established the impact of alcohol outlet density on violent injury, but little research explores the relationship between alcohol outlets and unintentional injury (Popova et al., 2009). Extant research on pedestrian injury and alcohol outlets has largely been descriptive, and many of these studies aimed to establish the relevance of the physical environment to the geographic distribution of pedestrian injury and to tackle the methodological issues in data analysis (LaScala et al., 2001; Pulugurthaa et al., 2007). Furthermore, these studies attempt to quantify the relationship between pedestrian injury and alcohol outlets without taking into account the larger social and structural context in which injuries occur (LaScala et al., 2001). To date, no study has looked at the cumulative impact of alcohol outlets, the built environment and the social environment on pedestrian injury risk.

This study has important implications for understanding the impact of alcohol outlets on pedestrian injury, as well as increasing the evidence base to support public health policy around liquor store licensing, zoning, and enforcement. Findings will inform public health-based policy initiatives and community-level behavioral health interventions addressing alcohol use and abuse, as well as pedestrian injury prevention.

CONCEPTUAL MODEL

The conceptual model displayed in Figure 1.1 adapts a framework proposed by Northridge and colleagues (2003) that conceptualizes the mechanisms by which the built environment impacts health status. This adapted model conceptualizes the mechanisms by which alcohol outlets and the built and social environments impact pedestrian injury. It incorporates the concept of reciprocal determinism from Social Cognitive Theory—the dynamic interaction of the person, the behavior and the environment in which the behavior is performed—to illustrate how structural/environmental factors, interpersonal relationships, and individual cognitive and biological events can manifest in pedestrian and driver behavior (Bandura, 1978). The scope of this research study focuses primarily on the structural-level factors which contribute to pedestrian injuries in areas around alcohol outlets. The literature review presented in Chapter 2 is organized by the individual components of this conceptual model and will clarify their connections.

Figure 1.1: Conceptual Model



STUDY AIMS

Research Aim 1: Describe the prevalence and distribution of pedestrian injury in Baltimore City

Objective 1: Demonstrate that local pedestrian injury trends differ from national pedestrian injury trends in significant and meaningful ways

Objective 2: Investigate city-wide pedestrian injury trends to assess pedestrian injury risk among nationally-identified risk groups

Objective 3: Identify pedestrian injury risk groups and locations specific to Baltimore City

Research Aim 2*:* Address the lack of a comprehensive database cataloging traffic safety infrastructure in Baltimore City

Objective 1: Create and validate a neighborhood environmental observational assessment tool to capture evidence-based pedestrian safety infrastructure

Objective 2: Validate the tool for use in Google Street View

Research Aim 3: Investigate the impact of the neighborhood presence of alcohol outlets on pedestrian injury

Objective 1: Establish a relationship between neighborhood presence of alcohol outlets and relative risk for pedestrian injury

Objective 2: Investigate the impact of physical disorder on pedestrian injury

Objective 3: Investigate the impact of the social environment on pedestrian injury

DISSERTATION ORGANIZATION

This dissertation is organized into six chapters and includes three manuscripts:

Chapter 1: Introduction

This chapter provides an overview of the importance of alcohol outlets on pedestrian injury risk. It also includes the aims and objectives for this dissertation, as well as the conceptual model.

Chapter 2: Literature review

This chapter provides a comprehensive review of the existing literature on risk factors for pedestrian injury and the association between alcohol outlets and pedestrian injury. It also discusses the impact of the physical and social environment on pedestrian injury risk, as well as the psychosocial manifestations of built and social environment factors. It includes a discussion of the theoretical frameworks supporting this research.

Chapter 3: Epidemiology of pedestrian injury in a mid-Atlantic city

The first manuscript is a descriptive epidemiologic study of pedestrian injury in Baltimore City. It provides a macro-level view of pedestrian injury across the city and identifies demographic and geographic risk groups without making assertions about injury risk factors. It includes a comparison of citywide trends to national trends to better understand Baltimore City's distinctive pedestrian injury risk patterns.

Chapter 4: Novel methods for environmental assessment of pedestrian injury

The second manuscript presents a validation study of Inventory of Pedestrian Safety Infrastructure (IPSI). It provides a tool for a granular analysis of the Baltimore streetscape. As no comprehensive database cataloging Baltimore City's traffic safety infrastructure exists, the IPSI provides a useful and necessary tool for investigating local pedestrian safety risk factors.

Chapter 5: The neighborhood alcohol environment and pedestrian injury risk

The third manuscript demonstrates that the neighborhood presence of alcohol outlets impacts the relative risk for pedestrian injury. It explores the impact of established neighborhood-level pedestrian injury risk factors, such as traffic volume and median household income, and identifies new ones including vacant lots.

Chapter 6: Discussion

The sixth chapter provides a summary of findings and conclusions from the three studies conducted as a part of this dissertation, as well as strengths, limitations, and public health implications of this research.

Appendices

Appendix A provides a detailed discussion of the data sources used in Chapters 3 through 5. Appendix B provides detailed maps of all study variables discussed in Chapter 3 and Chapter 5. Appendix C provides more information on exploratory data analysis for spatial modeling in Chapter 5, while Appendix D presents the results of ordinary kriging used for select variables in Chapter 5. Appendix E summarizes the stepwise spatial modeling used to determine the final model presented in Chapter 5, and Appendix F discusses the appropriateness of zero-inflated regression for this study. Appendix G displays the IPSI data collection form discussed in Chapter 4, while Appendix H presents the IPSI field guide used by data collectors and Appendix I presents the IPSI training presentation used in Chapter 4. Appendix J summarizes Exploratory Factor Analysis for the IPSI Roadway and Intersection Scales presented in Chapter 4.

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CHAPTER 2. LITERATURE REVIEW

BACKGROUND

Risk Factors for Pedestrian Injury

In 2014, there were 4,884 pedestrians killed and an estimated 65,000 injured in traffic crashes in the United States (National Center for Statistics and Analysis, 2016). A pedestrian was killed every two hours and injured every eight minutes in traffic crashes on average in 2014 (National Center for Statistics and Analysis, 2016). The risk of injury to pedestrians in the United States is significantly greater than that experienced by their European counterparts when looking at pedestrian deaths per distance traveled (Pucher & Dijkstra, 2003). The greater safety among European pedestrians can be attributed to an extensive effort to design and build transportation systems that focus on safe walking, while restricting motor vehicle use and reducing vehicle speeds (Pucher & Dijkstra, 2003). Risk factors for pedestrian injury in the United States can be broadly categorized into six main factors: pedestrian characteristics, driver characteristics, motor vehicle characteristics, roadway/built environment characteristics, environmental factors, and crash characteristics (Eluru et al., 2008; Mohamed et al., 2013).

Pedestrian Characteristics

Pedestrian characteristics which may influence injury risk include factors such as age, gender, or intoxication status. Intoxication's impact on pedestrian injury is discussed in more detail on page 21. Younger pedestrians and older pedestrians, with smaller and more frail bodies, are disproportionately represented in fatal crashes (B. Campbell et al., 2004; Moudon et al., 2011). In 2014, 19% of national pedestrian fatalities occurred among children age 14 and younger, and 17% occurred among adults age 65 and older (National Center for Statistics and Analysis, 2016). One reason for the high rate of pedestrian injury among children under age 14 is that road crossing is a complex behavior, and preadolescent children lack the cognitive ability to make well-planned crossing decisions (Retting et al., 2003; Stavrinos et al., 2009). Young children may not have developed “the cognitive and perceptual skills necessary to simultaneously perceive and process the distance, speed, and acceleration patterns of at least two vehicles, as well as the distance across the street and the speed within which they can cover that distance” (Stavrinos et al., 2009, p. e179). Consequently, children exhibit different road-crossing behaviors compared to older pedestrians which may contribute to their injury risk. For example, a New York City study of injured children age 15 and younger found that children age 10 and under were more likely to be struck at areas of the street where there were no traffic controls such as midblock; this indicates possible behavior-related crash antecedents, including emerging from between parked cars, playing in the street, and “dart and dash”[1] crossing in this age group (DiMaggio & Durkin, 2002). Older children were more likely to be hit at locations where there were traffic controls, such as intersections (DiMaggio & Durkin, 2002). Incidence of pedestrian injuries in children shows great geographic variability; much of this geographic variation may be attributable to different transportation patterns (Durkin et al., 1999). In urban areas, walking may be a more common mode of transportation for children, especially in families that do not own cars (Durkin et al., 1999).

Older pedestrians experience high fatality risk despite walking less and crossing fewer streets than younger pedestrians (Nicaj et al., 2006). A Maryland study found that older adults living in urban areas considered themselves at increased risk for pedestrian injury and were more observant of traffic safety procedures than their suburban or ex-urban

[1] A dart and dash road crossing is defined as “pedestrian appeared suddenly in the path of the vehicle or the pedestrian was running,” either midblock or at an intersection (Preusser et al., 2002, p. 705).

counterparts (Reed & Sen, 2005). Because of physical changes related to aging, older pedestrians take longer to cross the street, which may put them at increased risk despite exhibiting safe crossing behavior (Nicaj et al., 2006). Crosswalks may give older pedestrians a false sense of security when crossing the street, particularly at intersections with crosswalk markings but without traffic signals or stop signs (Koepsell et al., 2002). There is also evidence that fear of falling could influence crossing behavior among older pedestrians as older pedestrians may pay less attention to traffic and more attention to the pavement and their footsteps when crossing (Avineri et al., 2012).

A handful of studies have examined demographic and psychosocial correlates of pedestrian crossing behaviors. Nationally, in 2014 70% of pedestrian fatalities occurred among men (National Center for Statistics and Analysis, 2016). Men take greater risks in road crossing than do women (Rosenbloom, 2009). Women tend to perceive themselves as more susceptible to an accident while crossing against the signal compared to men (Yagil, 2000).

Distractions from multimedia devices and cell phones have also created new risk factors for pedestrian safety (Schwebel et al., 2012). Technology use while walking distracts attention away from the street environment and towards mobile phones or other electronic devices (Basch et al., 2015; Schwebel et al., 2012). An observational study of five busy Manhattan intersections found that one-third of pedestrians who crossed on a "Walk" signal and 42% who crossed on a "Don't Walk" signal were wearing headphones, talking on a mobile phone, and/or looking down at an electronic device (Basch et al., 2015). A study of children's cell phone use found that, while walking and talking on a cell phone, children were less attentive to traffic; left less safe time between their crossing and the next arriving vehicle; experienced more collisions and close calls with oncoming traffic; and waited longer before beginning to cross the street (Stavrinos et al., 2009). Increased familiarity and comfort with cell phone use did not decrease distraction or increase safe walking behavior (Stavrinos et al., 2009). Studies of older adults have shown similar results, with mobile phone-related injuries highest for pedestrians under age 31 (Byington & Schwebel, 2013; Nasar & Troyer, 2013; Schwebel et al., 2012). Hyman and colleagues (2010) found that adult cell phone users walked more slowly, changed directions more frequently, and were less likely to notice an unusual activity along their walking route compared to other pedestrians. There is also evidence that technology use while walking alters gait patterns and reduces gait speed, increasing road crossing time and riskier road crossing behaviors (Licence et al., 2015). Altered gait associated with distracted walking may also increase risk for tripping, collision or injuries to other non-distracted pedestrians attempting to avoid distracted walkers (Licence et al., 2015).

Driver Characteristics

Driver characteristics such as age and intoxication also contribute to pedestrian injury risk. While several studies have shown that pedestrians are more often at fault for pedestrian-involved crashes than drivers (J.-K. Kim et al., 2008; Lee & Abdel-Aty, 2005; Preusser et al., 2002; Ulfarsson et al., 2010), this might be a location-specific finding as a Hawaiian study found drivers to be responsible for a crash 12 times more often than pedestrians (K. Kim et al., 2008). Nevertheless, driver characteristics still contribute to crash occurrence. Drivers involved in pedestrian crashes tend to be middle aged (age 25-54) and male (J.-K. Kim et al., 2008). Driver alcohol use also contributes to risk of a pedestrian-involved crash, particularly at night (Lee & Abdel-Aty, 2005). Distraction may also increase crash risk as drivers distracted by entertainment systems or mobile phones are less able to respond to variable road conditions and pedestrian hazards (Young & Regan, 2007).

Almost one-fifth of the pedestrians killed in 2014 were struck by hit-and-run drivers (National Center for Statistics and Analysis, 2016). Hit-and-run drivers are more likely to be male, age 25 or younger, have prior violations, prior license suspensions, drive a vehicle more than five years old and have an invalid driver's license (MacLeod et al., 2012). Hit-and-run drivers are also more likely to be intoxicated at the time of a crash and are more likely to have a previous arrest for driving while intoxicated compared to drivers who remain at the scene of an accident (Solnick & Hemenway, 1994).

Driver behavior also influences pedestrian behavior, increasing injury risk. An observational study of pedestrian and driver behavior found that the majority of turning vehicles failed to give priority to pedestrians during the pedestrian green phase of a crossing signal (Sisiopiku & Akin, 2003). This driver behavior increased the likelihood that pedestrians did not select to cross at signalized crosswalks during the pedestrian green phase, particularly if pedestrians had a crossing alternative that reduced delays and provided safer crossing conditions (Sisiopiku & Akin, 2003).

Vehicle Characteristics

Characteristics of the vehicle itself are also important in determining pedestrian injury risk and severity. Different vehicle types may be more dangerous to pedestrians because of variations in vehicle mass, vehicle speeds, and front vehicle design (Ballesteros et al., 2004). The likelihood of a pedestrian-involved crash increases with vehicle operating speeds (Ewing & Dumbaugh, 2009). A pedestrian struck by a vehicle traveling 40 miles per hour has an 85% chance of being killed; this fatality rate drops to 45% at vehicle speeds of 30 miles per hour and 5% at 20 miles per hour or less (Ewing & Dumbaugh, 2009). A Maryland study found that sport utility vehicles and pick-up trucks were associated with more pedestrian deaths and more severe injuries compared to pedestrians hit by conventional cars; however, these relationships diminished when vehicle weight and speed were controlled for (Ballesteros et al., 2004). At lower speeds, pedestrians struck by larger vehicles were more likely to have traumatic brain, thoracic, and abdominal injuries; at higher speeds, there was no such association (Ballesteros et al., 2004). This suggests that, at lower speeds, the risk to pedestrians posed by these larger vehicles may be attributable to vehicle design, particularly the front of the vehicle which comes into contact with the pedestrian (Ballesteros et al., 2004).

Roadway Characteristics

Roadway characteristics which impact pedestrian injury risk include characteristics of the streetscape, such as the number of street lanes or speed limit, as well as characteristics of the surrounding built environment, including street connectivity and patterns of land use. Built environment characteristics are discussed in more detail on page 24. In 2014, 78% of pedestrian fatalities occurred in urban areas, and characteristics of urban roadways will be the focus of this discussion (National Center for Statistics and Analysis, 2016). Roadway engineering modifications designed to protect pedestrians from vehicles generally can be classified into three broad categories: separation of pedestrians from vehicles by time or space, increased visibility and conspicuity of pedestrians, and reductions in vehicle speeds (Retting et al., 2003).

Some of the most effective strategies for preventing pedestrian injury involve separating pedestrians in time and space from motor vehicles (Frumkin et al., 2004; Staunton et al., 2007). These strategies include installation of traffic signals, pedestrian overpasses, fences to inhibit street access, wide sidewalks with deep curbs, and stop lines in advance of crosswalks (Retting et al., 2003; Schuurman et al., 2009; Staunton et al., 2007). Several studies using spatial analysis to explore risk factors for pedestrian injuries have shown that pedestrian-involved crashes are more likely in areas where these safety features are lacking or absent (Dai et al., 2010; Miranda-Moreno et al., 2011; Schuurman et al., 2009).

Pedestrian visibility is an important injury risk factor. Roadway lighting at night, when almost three-quarters of pedestrian fatalities occur, can increase pedestrian visibility to drivers (National Center for Statistics and Analysis, 2016; Retting et al., 2003). Increased intensity of roadway lighting, particularly at pedestrian crossings, is associated with significant reductions in nighttime pedestrian crashes (Retting et al., 2003). A Florida study found that street lighting reduced the odds of a pedestrian fatality by 42% at midblock locations and by 54% at intersections (Siddiqui et al., 2006). On-street parking—particularly parallel parking—obscures driver and pedestrian vision, and interventions which alter the manner in which vehicles can park such as diagonal parking or removal of on-street parking reduce the risk of pedestrian-involved crashes (Agran & Winn, 1996; Retting et al., 2003). Bus stops may also decrease pedestrian visibility to drivers as pedestrians may enter the roadway in front of the bus or cross the street in an unsafe manner to catch the bus (Brenac & Clabaux, 2005; Unger et al., 2002; Zegeer & Bushell, 2012).

Reducing vehicle speed also impacts pedestrian injury risk and severity. Replacing conventional intersections with roundabouts is the most effective speed control intervention for pedestrian safety (Retting et al., 2003). European studies show that replacing conventional intersections with roundabouts reduces the rate of pedestrian-involved crashes by up to 75% (Schoon & Van Minnen, 1994). Other speed management approaches include multiway stop signs and traffic calming techniques such as lane narrowing, adjustments to roadway curvature, and speed humps (Retting et al., 2003). Street width is an important pedestrian injury risk factor as pedestrian-involved crashes are more common on two-way streets than one-way streets (Dai et al., 2010). However, the literature on the effectiveness of reducing traffic speed through infrastructure improvements to prevent pedestrian injury has been mixed (Retting et al., 2003). A systematic review of case-control studies found no evidence that traffic calming schemes prevent pedestrian-vehicle collisions; however, it is possible that traffic-calming measures reduce injury severity in the event of a crash (Bunn et al., 2009).

Roadway characteristics also impact pedestrian behavior. Even when pedestrian safety infrastructure is in place, pedestrians may not use it in a manner that optimizes their safety. For example, a Michigan study found that pedestrians cross at legally-designated crossings 59% of the time, yet only wait for a green signal before crossing 10% of the time (Sisiopiku & Akin, 2003). Street width may also impact pedestrian behavior as pedestrians are more likely to cross illegally on narrower streets or on streets with a median refuge (Ishaque & Noland, 2008; Li & Fernie, 2010). Excessive delay at street crossings also decreases compliance at signalized crosswalks (Ishaque & Noland, 2008; Li & Fernie, 2010).

Environmental Factors

Environmental factors such as time of day and weather conditions influence pedestrian injury risk. Pedestrian-involved crashes which occur during nighttime and in adverse weather conditions have increased likelihood of pedestrian fatality (Eluru et al., 2008). For example, rainy conditions significantly decrease pedestrian visibility and significantly increase risk of a pedestrian-involved crash despite roadway lighting (Wanvik, 2009). There is also evidence that weather influences pedestrian crossing behavior. Pedestrians have been found to have lower proper road crossing rates in cold weather or inclement weather such as snowy conditions compared to warm, dry weather (Li & Fernie, 2010). However, some of the impact of environmental conditions on injury risk and risk behavior may be related to characteristics of the pedestrian or driver. A study of pediatric pedestrian injury in New York City found the majority of crashes involving child pedestrians occurred during daylight hours and during the summer months on dry roads when the weather was clear (DiMaggio & Durkin, 2002). In other words, children were more likely to be struck during environmental conditions conducive to outdoor play.

Crash Characteristics

The characteristics of the crash itself—the vehicle's and pedestrian's motions prior to the accident—also influence pedestrian injury risk and severity. Common antecedents of a crash where the driver was at fault include striking a pedestrian off-road, failing to grant a pedestrian the right of way, speeding, driving outside the proper traffic lanes, and losing control of the vehicle (Preusser et al., 2002). Common antecedents of a crash where the pedestrian was at fault include the pedestrian running into the street, crossing a high-speed highway, and crossing against the light (Preusser et al., 2002). The majority of pedestrian-involved crashes occur at intersections; of these, the majority of vehicles were traveling straight (Roudsari et al., 2006). The second most common trajectory for accidents at intersection was left turns (Roudsari et al., 2006). Injuries caused by turning vehicles are generally less severe than injuries caused by vehicles moving straight because of lower speeds traveled by turning vehicles (Moudon et al., 2011; Roudsari et al., 2006). Although most pedestrian-involved crashes occur at intersections, injuries which occur at intersections are general less severe (Eluru et al., 2008). Crossing the street midblock increases the likelihood of a severe or fatal pedestrian injury (Moudon et al., 2011; Siddiqui et al., 2006).

Alcohol Outlets and Pedestrian Injury

According to the National Highway Traffic Safety Administration, alcohol consumption was involved in 48% of motor vehicle crashes that resulted in pedestrian fatalities in 2014 (National Center for Statistics and Analysis, 2016). Of the pedestrians involved in fatal crashes, 34% had blood alcohol concentration (BAC) of 0.08 g/dL or higher, while only 14% of drivers involved in these pedestrian crashes had BAC of 0.08 g/dL or higher (National Center for Statistics and Analysis, 2016). Consequently, excessive alcohol consumption is a leading contributor to pedestrian injury and fatality in the United States. Alcohol consumption adversely affects the observational, cognitive, and physical skills of pedestrians, including detecting vehicles in motion, integrating multiple sources of information, and initiating actions (Oxley et al., 2006). As a result, pedestrians who consume alcohol are more likely to cross the street in an unsafe manner. One study found that when pedestrians had consumed alcohol, they were less likely to cross the street in the crosswalk with the signal and more likely to cross either in the crosswalk against the signal or midblock (Dultz et al., 2011). Intoxicated pedestrians are also more likely to be on the street at times when or in locations where it is dangerous for other reasons, such as after dark or in high-speed traffic corridors (Hutchinson et al., 2010). A Florida study found that the impact of alcohol use on risk of a nighttime crash was higher for crashes where the pedestrian was at fault than where the driver was at fault, indicating that pedestrian's intoxication status was more of a risk factor for nighttime crashes than driver intoxication (Lee & Abdel-Aty, 2005). Injured pedestrians who consume alcohol also experience more severe injuries compared to sober pedestrians. Pedestrians who have consumed alcohol at the time of a crash experience higher rates of injury to the head and neck, face, chest, abdomen, and extremities and suffer longer recovery times compared to sober pedestrians (Dultz et al., 2011; Plurad et al., 2006).

However, the effect of alcohol outlets on pedestrian injury appears to extend beyond alcohol consumption by individuals as consumption patterns alone do not account for increased injury rates in communities where alcohol outlets are located. Alcoholic beverage outlet density refers to the "number of physical locations in which alcoholic beverages are available for purchase either per area or per population" (C. A. Campbell et al., 2009, p. 556). An outlet is a setting in which alcohol may be sold legally for either on-premises or off-premises consumption. On-premises settings include restaurants, bars, hotels, and ballparks; off-premises settings include grocery and convenience stores, as well as liquor and package stores and taverns that sell liquor, beer, and wine (C. A. Campbell et al., 2009; Milam et al., 2014). Studies on whether greater alcohol outlet density results in increased average alcohol consumption among residents have been mixed (Babor et al., 2010; Gmel et al., 2016; LaVeist & Wallace, 2000; Pollack et al., 2005). One study found that the effect of increased alcohol outlet density on injury was independent of the effect of increased alcohol consumption, suggesting that the social aggregation of drinkers in and around alcohol outlets directly affects injury (C. A. Campbell et al., 2009).

Furthermore, on- and off-premise outlets may differentially impact injury risk. Off-premise outlets are more strongly associated with drinking problems, crime, and violence (Branas et al., 2011; Furr-Holden et al., 2016; Schonlau et al., 2008). Unlike bars and restaurants, off-premise alcohol outlets can sell alcoholic beverages in large quantities that can be consumed in uncontrolled environments such as motor vehicles, liquor store parking lots, or at home (LaVeist & Wallace, 2000). In bars and restaurants, servers control consumption and can halt service to intoxicated patrons (Milam et al., 2014). The unrestrained environment around off-premise vendors, combined with the ability to purchase large quantities of alcohol, may lead to excessive consumption and increased injury risk (Milam et al., 2014; Pollack et al., 2005).

While few studies have examined the impact of alcohol outlets on pedestrian injury, the majority of these studies focused on alcohol-involved crashes—crashes where the pedestrian, the driver, or both were intoxicated (DiMaggio et al., 2016; Escobedo & Ortiz, 2002; LaScala et al., 2001; Treno et al., 2007). Few studies have examined the impact of alcohol outlets on pedestrian injury risk above and beyond that attributable to intoxication, and no studies have examined this relationship independent of intoxication. However, there is some evidence that pedestrian injury hotspots overlap areas of greater alcohol outlet density. In a study conducted in Vancouver, two-thirds of pedestrian injury hotspots were located immediately proximal to an alcohol outlet, and almost one-third of all hot spots were located in areas of high alcohol outlet density (intoxication was not measured as part of this study) (Schuurman et al., 2009). The occurrence of pedestrian injuries in areas of greater alcohol outlet density may be a result of the diverse social and physical characteristics of the community in which the injuries occur (Gruenewald, 2007; Toomey et al., 2012; Treno et al., 2007). Little research exists which conceptualizes the mechanisms by which alcohol outlet density impacts pedestrian injury risk. Extant research points to the built and social environments as possible mediators of the relationship between alcohol outlet density and pedestrian injury.

Impact of the Built Environment on Pedestrian Injury

Defining the Built Environment

The built environment includes "aspects of a person's surroundings which are human-made or modified," such as land use and transportation systems (Papas et al., 2007, p. 130). Three dimensions of the built environment influence neighborhood walkability and pedestrian safety: land use patterns, design characteristics, and transportation systems (Frank et al., 2003). Land use patterns concern large scale spatial arrangement of commercial, residential and physical activity zones across the metropolis (Frank et al., 2003). Design characteristics include the architecture of buildings, placement of sidewalks, or presence of tree canopies which create a sense of place (Frank et al., 2003). Transportation systems connect different land uses through walking, bicycling, mass transit, or driving (Frank et al., 2003). Characteristics of the built environment such as a feeling of physical safety or "eyes on the street," the integration of parkland into city life, and the need for mixed function residential and commercial property which encourage utilitarian as well as recreational activity further influence neighborhood walkability and pedestrian safety (Casteel & Peek-Asa, 2000; Jacobs, 1989).

The Built Environment and Pedestrian Injury

Built environment features that prevent pedestrian injury are well-established in the literature. Specific street infrastructure features which prevent pedestrian injury and reduce injury severity are discussed in greater detail on page 17. In addition to specific characteristics of streetscapes, land use patterns and population density also impact pedestrian injury risk and severity. The convergence of people and vehicles at popular destinations such as workplaces, restaurants, bars, and recreation and entertainment venues may provide more opportunities for pedestrians and vehicles to interact, increasing crash risk (Dai et al., 2010). Land use patterns in cities and suburban areas may be characterized by sprawl. Sprawl can be defined as a pattern of residential growth consisting of dispersed, low-density, auto-dependent development outside compact urban and village centers (Frumkin et al., 2004; Squires, 2002). Sprawled environments are characterized by "rigid separation of homes, shops, and workplaces; a lack of distinct, thriving activity centers, such as strong downtowns or suburban town centers; and a network of roads marked by very large block size and poor access from one place to another" (Ewing et al., 2003, p. 1541).

The sprawled quality of the urban landscape may play an important role in pedestrian injury risk. A study of 356 counties across the United States found that for every 1% increase in the urban compactness index—indicating decreasing sprawl—the pedestrian fatality rate decreased by 3% (Ewing et al., 2003).[2] These findings are supported by several studies which associated densely-populated urban areas with decreased pedestrian injury risk and severity. A review of urban planning studies for traffic safety found that dense urban areas are characterized by roadway designs that hinder traffic flow and reduce vehicle speeds, such as narrow lanes, traffic-calming infrastructure and trees close to roadways (Ewing & Dumbaugh, 2009). Consequently, dense urban areas were safer for pedestrians than lower traffic volume suburban regions as fewer miles per capita were driven in urban areas, and driving is done at consistently lower speeds that are less likely to produce pedestrian-involved crashes (Ewing & Dumbaugh, 2009). A Baltimore injury severity study found that access to mass transit and increasing pedestrian connectivity[3] were negatively associated with pedestrian injury severity (Clifton et al., 2009). A study of road patterns common to sprawled, suburban communities found that, compared to gridiron street patterns, loop-and-lollipop street patterns[4] were associated with a higher likelihood of non-fatal pedestrian injury (Rifaat et al., 2011). While the curvilinear nature of loop-and-lollipop roads reduces vehicle speeds overall, this street design also reduces sight distances, increasing impact speeds and the probability of a pedestrian-involved crash (Rifaat et al., 2011). These findings were supported by a comparative analysis of pedestrian injury fatality risk in New York and Montreal, which found that built environment features related to denser and more urbanized areas with lower vehicle speeds reduced crash fatality risk (Mohamed et al., 2013).

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[2] According to this study, Baltimore City was the 10th most compact county compared to 448 counties (Ewing et al., 2003).

[3] Street networks that are more connected are thought to increase walkability; those that include longer blocks, fewer intersections, and more dead-ends are less conducive to walking (Berrigan et al., 2010).

[4] A loop-and-lollipop street pattern is a limited access street pattern where roads are curvilinear and often dead end in cul-de-sacs (Rifaat et al., 2011).

The Built Environment and Alcohol Outlets

Evidence from spatial analysis studies of pedestrian injury and other types of traumatic injury demonstrates that the built environment moderates the association between injury risk and alcohol outlet density. A Vancouver study found that pedestrian injuries were more likely in areas of concentrated alcohol outlets because they lacked traffic calming and other safety infrastructure (Schuurman et al., 2009). In a study of violent assault, the strength of the association between alcohol outlet density and injury was weaker in block groups with a higher proportion of single-family residences and a higher proportion of commercial land use; the association was stronger in block groups with more heavy industry and more public housing (Pridemore & Grubesic, 2012).

It may be advisable to implement tailored pedestrian injury prevention strategies in areas of high alcohol outlet density to mitigate pedestrian injury risk (Clifton et al., 2009; Schuurman et al., 2009). Currently, interventions designed to protect pedestrians around alcohol outlets are intended for intoxicated pedestrians and drivers, not to address social and physical mechanisms which may accumulate around alcohol outlets. These prevention efforts are broadly designed to reduce alcohol consumption in intoxicated pedestrians, reduce pedestrian activity in those who are intoxicated, or minimize the risk of injury among intoxicated pedestrians (Hutchinson et al., 2010). Nevertheless, some of these interventions may reduce pedestrian injury around alcohol outlets regardless of the intoxication status of pedestrian or driver. For example, an Australian study suggested installing specific environmental countermeasures such as enhanced street lighting, medians or traffic islands, skid-resistant surfaces, and highly responsive pedestrian-operated crossing signals in areas of concentrated alcohol outlets (Corben et al., 1996).

Impact of the Social Environment on Pedestrian Injury

Defining the Social Environment

The social environment concerns the context in which people live, work, and form relationships and includes social capital, collective efficacy and social disorganization. Broadly defined, social capital consists of "resources stemming from the structure of social relationships, which in turn facilitate the achievement of specific goals" (Sampson, 2003, p. 135). Social capital is particularly important in impacting collective efficacy—the ability of a community to organize around communal goals (Sampson, 2003). Social capital may also include bonding and bridging social capital (Putnam, 2000). Bonding, or horizontal, social capital results from exchanges among close-knit groups and reflects the scale of social connectedness individuals have with others in their immediate lives, including friends, families, neighbors, and co-workers (Putnam, 2000). Bridging, or vertical, social capital is a property of individuals' and social networks' connections to other individuals and networks outside of a person's immediate network, and perhaps very far from it (Putnam, 2000). A neighborhood may have high bonding social capital in that residents come together to organize for a common goal, but it may have low bridging social capital in that it is difficult for the group to achieve their aims (Altschuler et al., 2004).

Residential stability is particularly important to developing social capital in communities and countering neighborhood disorder. Residential stability permits the growth of local social ties, leading to social cohesion and, subsequently, to local attachment (Sampson, 1991). Residential stability also enhances residents' efforts to counter disorder, reducing feelings of personal vulnerability (Taylor, 1996). Physical disorder refers to the deterioration of the urban landscape, evidence of which includes graffiti, litter, and broken windows (Sampson & Raudenbush, 1999). Social disorder indicates behavior from strangers which may be considered threatening, such as verbal harassment on the street, public intoxication, or solicitation of prostitutes (Sampson & Raudenbush, 1999). Socially disorganized neighborhoods are also characterized by "the inability of local communities to realize the common values of their residents or solve commonly experienced problems" (Bursick, 1988, p. 521). Socially disorganized neighborhoods have been described as having low collective efficacy, weak informal local friendship networks, and low participation of residents in local organizations (Sampson & Groves, 1989).

It is important to note that residential stability may not translate into increased social cohesion in more economically disadvantaged neighborhoods because residents may be relatively trapped because of an economic inability to move and not because of a sense of attachment to the neighborhood (Hipp, 2010). If residents in these neighborhoods do not socialize because of fear of neighborhood crime, this longer residence will not translate into greater social interaction and cohesion (Hipp, 2010). However, in some neighborhoods, crime and other forms of social deterioration may draw residents together, providing an external threat to combat, while at the same time increasing feelings of vulnerability (Taylor, 1996).

The Social Environment and Pedestrian Injury

Previous research suggests that the ability of a community to respond to road safety issues is closely correlated with socio-economic privilege and social capital (Collins & Kearns, 2005). This suggests that communities that have higher social capital and collective efficacy can more effectively come together when the need arises to promote changes to benefit the public good, such as putting in a speed hump or preventing new bars or liquor stores from opening (Altschuler et al., 2004). One qualitative study found that higher income neighborhoods in one metropolitan area were more successful and quicker at bringing about change compared to lower income neighborhoods in part because of their greater bridging social capital (Altschuler et al., 2004). Despite the organization and motivation of residents in the lower income neighborhood, it took them significantly longer to achieve their goals in increasing road safety because they lacked bridging social capital (Altschuler et al., 2004).

No quantitative studies could be found which explored the mechanisms through which the social environment impacts pedestrian injury risk. A review of studies on the impact of neighborhood safety on children's physical activity found that living in a neighborhood characterized by social disorder significantly decreased children's outdoor play time, but this was not extended to a discussion of pedestrian injury risk (Carver et al., 2008). Much of the research examining the influence of the social environment on unintentional injury has focused on community demographics and population-level measures of disparity. One study of traumatic injury across Canada and the United States found that locations of injuries were not geographically random; rather, injury events disproportionately clustered in census tracts with higher rates of unemployment, lower educational levels, lower incomes, fewer families, and more non-White residents (Newgard et al., 2011). These findings are supported by similar studies of traumatic injury (Cusimano et al., 2010; Gruenewald et al., 2006; LaScala et al., 2000). In a Montreal study, there was a statistically significant inverse relationship between median household income and average number of injured pedestrians in a census tract (Morency et al., 2012). Traffic volume was also higher in poorer census tracts versus wealthier census tracts (Morency et al., 2012). A Toronto study found that closing time for alcohol outlets coincided with a distinctive geographic shift in injury location to areas characterized by a high number of bars and clubs and few residents (Cusimano et al., 2010). These findings point to behavioral and social factors in the immediate environment of alcohol outlets that may be associated with temporal shifts in injury occurrence.

The Social Environment and Alcohol Outlets

Resource-deprived census tracts and predominantly African American census tracts have significantly more liquor stores per capita than more affluent communities and predominantly white communities (LaVeist & Wallace, 2000). This concentration of outlets is not necessarily related to demand for alcohol in these communities. Rather, national individual-level data show lower overall alcohol consumption by African Americans compared to non-Hispanic Whites (Romley et al., 2007). One California study found that, although the most resource-deprived neighborhoods had the highest density of alcohol outlets, living in the most deprived neighborhoods was not related to heavy drinking; respondents who lived in the least deprived neighborhoods had the highest levels of heavy alcohol consumption, even after controlling for a range of individual characteristics (Pollack et al., 2005). However, research on this overlap has been mixed, with other studies pointing to a strong association between supply of alcohol and increased alcohol consumption (Babor et al., 2010; C. A. Campbell et al., 2009)

The discrepancy between alcohol supply and demand in a community may cause residents of resource-deprived neighborhoods to disproportionately suffer the negative health consequences of living near alcohol outlets (Pollack et al., 2005). Alcohol outlets, particularly off-premises packaged goods stores, are often surrounded by signs of social and physical disorder, such as empty or broken bottles, loiterers, and publicly intoxicated patrons (Cunradi, 2010). Greater alcohol outlet density in and of itself is a visible indication of increased disorder and loss of social control. Together with other deleterious neighborhood conditions, the presence of alcohol outlets signals to residents that the mechanisms of informal social control are not working (Cunradi, 2010; Gorman et al., 2001).

One study found that off-premise alcohol outlet density was strongly associated with reduced social capital, suggesting that off-premise alcohol outlets may hinder the development of social capital in a neighborhood (Theall et al., 2009). Furthermore, perception of neighborhood safety mediated the relationship between collective efficacy and alcohol outlet density (Theall et al., 2009). In neighborhoods perceived as being unsafe, residents may be less likely to spend time outdoors and to network in a way that builds social capital as community members may be competing with social networks associated with disorder, crime, and other incivilities[5] surrounding alcohol outlets (Theall et al., 2009). An alcohol outlet in a neighborhood embodies a focal point for incivilities associated with physical and social disorder (Scribner et al., 2007). Consequently, the presence of alcohol outlets may hinder the expansion of a positive underlying neighborhood social network and lead to competing, deleterious social networks (Jacobs, 1989; Scribner et al., 2007).

The Built and Social Environments Interact

The built and social environments influence each other. Patterns of neighborhood design influence the sense of community and pride in a neighborhood (Jacobs, 1989). In

[5] "Incivilities" are defined as visible evidence of disorder (Sampson & Raudenbush, 1999). "Incivility indicators are social and physical conditions in a neighborhood that are viewed as troublesome and potentially threatening by its residents and users of its public spaces" (Taylor, 1999, p. 65).

turn, social features such as social capital and collective efficacy influence a community's ability to promote beneficial zoning regulations or safety features (S. Wilson et al., 2008). The built environment and patterns of neighborhood design greatly impact social capital. For example, urban sprawl undermines social cohesion and social network creation, damaging opportunities to create social capital. Urban sprawl restricts the time and energy people have available for civic and social involvement because of the demands of commuting. One study showed that every 10 additional minutes of daily commute time reduced a commuter's involvement in community affairs by 10% (Putnam, 2000). Sprawl also reduces opportunities for spontaneous, informal interaction. Neighborhoods zoned only for residential purposes lack amenities such as cafés, coffee shops, bookstores, and other hangouts where people traditionally gather to socialize (Baum & Palmer, 2002; Frumkin et al., 2004). Compared to neighborhoods with mixed use residential and retail opportunities, single-use residential neighborhoods have less sense of community (Nasar & Julian, 1995). Finally, sprawl places a higher value on the individual and private space. Relative to urban and small-town voters, voters in sprawled communities place little emphasis on such social goals as reducing poverty and tend to reject initiatives such as park creation and mass transit (Frumkin et al., 2004).

The built environment also mediates the relationship between injury risk and resource deprivation (Laflamme et al., 2010). One study found that the relationship between living in neighborhoods with concentrated poverty and risk of hospitalization for an injury was mediated by housing characteristics, specifically by owner occupancy and age of housing (Shenassa et al., 2004). Another study found that living in a resource-deprived neighborhood increased injury risk regardless of an individual family's personal economic circumstances (Haynes et al., 2003). Consequently, neighborhood-level characteristics may influence injury risk regardless of the characteristics of an individual resident such as socioeconomic status.

Theoretical Frameworks

Social Cognitive Theory provides a framework for conceptualizing how the built and social environments in areas with greater concentrations of alcohol outlets relate to personal factors and pedestrian and driver behavior. Social Cognitive Theory posits that behavior is the product of the dynamic interaction of the person, the behavior and the environment in which the behavior is performed (Bandura, 1978; McAlister et al., 2008). The theoretical construct of reciprocal determinism emphasizes an individual's potential ability to shape environments to suit their cognitive, affective or biological needs (Bandura, 1978; McAlister et al., 2008). As much as people shape the physical and social environment, the environment shapes the person. In addition to an individual's ability to interact with her environment, Social Cognitive Theory also emphasizes the ability of individuals to come together for collective action (Bandura, 1978; McAlister et al., 2008). The construct of reciprocal determinism may help conceptualize the mechanisms by which the built and social environments in areas of greater alcohol outlet density impact personal cognition and manifest in pedestrian and driver behavior.

Broken Windows Theory (BWT) attempts to conceptualize the impact of disorder on neighborhood functioning (J. Q. Wilson & Kelling, 1982). According to this theory, "the signs of disorder suggest that many neighbors do not respect other people or their property, that agents of social control are unable or unwilling to cope with local problems, and that the neighborhood has been abandoned and its residents must fend for themselves" (Hill et al., 2005, p. 172). The perception of criminal activity in the physical manifestation of disorder may cause more fear and concern among the public than empirical rates of serious crime (Chappell et al., 2011). An area marked by disorder is perceived as vulnerable to criminal activity, and anxious residents may withdraw from neighborhood life. Resulting social isolation and fear impede the development of collective efficacy, perpetuating a cycle of physical and social decline (Garvin et al., 2013). BWT supports the adjustment of modifiable environmental features, such as broken windows or abandoned buildings, as a strategy to stabilize the neighborhood environment before it becomes overly dilapidated and in need of more intensive intervention (Furr-Holden et al., 2011).

Psychosocial Manifestations of Built and Social Environment Factors

The mechanisms through which the built and social environments impact individual behavior in areas of greater alcohol outlet density are not well understood (Franklin et al., 2010). Research suggests alcohol-related violence stems from an individual's underlying personality characteristics, such as impulsiveness or aggression (Franklin et al., 2010). Situational context may exacerbate these latent characteristics (Franklin et al., 2010). Guided by the above-described theoretical frameworks (page 34), similar factors may be at play in antecedents of pedestrian injury. While not directly measured as part of this research study, an exploration of these factors is vital to understanding the mechanisms through which the built and social environments may impact pedestrian and driver behavior and resulting pedestrian injury.

Stressors and Psychosocial Responses to Neighborhood Disorder

The mechanisms by which social and physical disorder impact injury risk beyond safety infrastructure are not well understood. Physical disorder is theorized to lead to negative health outcomes by promoting chronic stress and associated maladaptive physiologic responses (Cohen et al., 2000; Garvin et al., 2013). Attributes of the built environment have been shown to predict individuals' levels of psychological distress, even after controlling for individual-level variables such as age, gender, and resource deprivation (Brown et al., 2009). Residents who report high disorder in their neighborhoods experience more depression, fearful anxiety, and signs of autonomic arousal than do those who report fewer neighborhood problems (Daniel et al., 2008; Hill et al., 2005).

There is also increasing evidence that neighborhood disorder impacts residents on a cellular and biological level. A recent study of children age 5 to 16 found that increased environmental stress is associated with cellular aging, Telomere shortening, and Telomere attrition (Theall et al., 2016). After adjusting for potential confounders, including exposure to neighborhood violence, Theall and colleagues (2016) found that the number of liquor stores within a 500 m radius of a child's home was associated with a decrease in mean Telomere length for each additional liquor store. Liquor store density was also associated with higher levels of cortisol and diminished cortisol level recovery ability (Theall et al., 2016). The long-term damage to the body from chronic exposure to these stressors is known as "allostatic load," defined as the "physiological costs of chronic exposure to…heightened neuroendocrine response that result from repeated or chronic environmental challenges" (Hill et al., 2005, p. 172). Prolonged activation of the stress response has been shown to have serious consequences for cardiovascular disease, mental illness, and general disease morbidity and mortality (Juster et al., 2010). It is unclear, however, whether and to what extent allostatic load and psychological distress contribute to pedestrian or driver behavior and resulting pedestrian injury.

Neighborhood disorder may further undermine mental health and increase depression risk as disordered neighborhoods exhibit fewer opportunities for social interaction and group involvement, decreasing social capital and increasing social isolation (Baum & Palmer, 2002; D. Kim, 2008; Wood et al., 2008). Social capital is a contributor to health in many ways: by serving as a source for information, identifying healthy behavior norms and attitudes; creating social ties and emotional support; and contributing to the ability to problem solve to achieve group gain (Frumkin et al., 2004). Social capital is particularly predictive of mental health outcomes as people with strong social networks are less likely to be depressed (Diez-Roux & Mair, 2010; Mair et al., 2008). Residential instability has also been linked to depression (Diez-Roux & Mair, 2010).

Residents of disordered neighborhoods may also experience a sense of powerlessness or lack of control over the quality and physical order of their neighborhoods, further undermining the mental health of community residents (Warr et al., 2009). An Australian study found that higher levels of neighborhood upkeep—or lower levels of neighborhood disorder—were associated with increased feelings of safety and higher levels of social capital (Wood et al., 2008). A qualitative study on the impact of vacant lots on community well-being in Philadelphia found that efforts to maintain the neighborhood were perceived as futile, contributing to a sense of helplessness and a perceived lack of community cohesion (Garvin et al., 2013). Residents felt a significant stigma associated with living in a decaying neighborhood and felt unfairly judged by outsiders, further contributing to self-reported sadness and depression (Garvin et al., 2013).

Creation of New Social Norms and Health Behaviors

The appearance of the physical environment may suggest which behaviors are acceptable in a neighborhood. For example, Ewing and Dumbaugh (2009) posit that roadway design features, such as narrow lanes, traffic-calming infrastructure and trees close to roadways, convey to drivers how to behave in a particular neighborhood. The presence of traffic-calming roadway features signals to drivers safe and appropriate operating speeds, which, in turn, may prevent behaviors which result in traffic crashes (Ewing & Dumbaugh, 2009).

In contrast, a disordered environment implies that behaviors that are usually unacceptable can be perpetrated without fear of consequences (Cohen et al., 2000; Cunradi, 2010). As neighborhood deterioration progresses, families with means often leave the area or the city. Possible role modeling or controlling factors contributed by these community residents—known as "social buffers" in Broken Windows Theory—are also lost (Cohen et al., 2000). Consequently, remaining community residents may opt to disregard social conventions or legal ordinances, such as crossing with the light in crosswalks or yielding to pedestrians when driving.

Alternatively, communities that experience high physical and social disorder may develop their own, internal social norms of incivility or violence (Haynes et al., 2003). Systematic social observations of street segments in Chicago found that neighborhoods with high levels of responsibility and trust experienced low levels of violent crime, when controlling for resource deprivation (Sampson, 1997). This suggests that more cohesive communities experience different social norms around incivility; however, this research has not been extended to the study of unintentional injury.

Protective Effects of the Built and Social Environments

It is important to note that poverty is not the same as disorder, and that areas of high poverty might experience low Broken Windows indexes (Cohen et al., 2000). In high-poverty neighborhoods with low Broken Windows indexes, residents may be more willing to act for the common good and maintain their homes and communities; the willingness to act for the common good may be reinforced by living in a neighborhood whose appearance signifies that rules and standards exist (Cohen et al., 2000; Pearson et al., 2013). Natural surveillance and aspects of neighborhood design protect neighborhoods from the deleterious impact of disorder, including crime (Casteel & Peek-Asa, 2000). Natural surveillance describes "architectural and neighborhood design features that promote direct observation and interaction among individuals in a building and individuals walking in the street" (Brown et al., 2009, p. 234). The presence of "eyes on the street" has been shown to prevent crime and improve mental health among neighborhood residents (Brown et al., 2009; Jacobs, 1989).

Routine traffic policing may also have a beneficial impact on community health and well-being regardless of socioeconomic status. Lax traffic enforcement can have the same effect as unaddressed neighborhood disorder by imparting a sense that police are either unconcerned or lack the ability to enforce community standards of conduct (Giacopassi & Forde, 2000). While minor traffic infractions may be seen as too petty to warrant strong enforcement, lax traffic enforcement may result in increased levels of driver aggressiveness; disregard for traffic safety rules increases the risk of motor vehicle crashes

(Giacopassi & Forde, 2000). Interestingly, research also indicates that traffic enforcement not only reduces motor vehicle-related injury and death, it also helps reduce serious crime as violators may be stopped and identified during traffic policing (Giacopassi & Forde, 2000). Understanding the impact of the built and social environments on behavior may, consequently, reveal useful strategies for health promotion programming and policy development.

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CHAPTER 3. EPIDEMIOLOGY OF PEDESTRIAN INJURY IN A MID-ATLANTIC CITY

ABSTRACT

Understanding pedestrian injury trends at the local level is essential for program planning and allocation of funds for urban planning and improvement. Because we hypothesize that local injury trends differ from national trends in significant and meaningful ways, we investigated city-wide pedestrian injury trends to assess injury risk among nationally-identified risk groups, as well as identify risk groups and locations specific to Baltimore City. Pedestrian injury data were gathered through EMS records collected from January 1 to December 31, 2014. Locations of pedestrian injuries were geocoded and mapped. Pearson Chi-square Test of Independence was used to investigate differences in injury severity level across risk groups. Pedestrian injury rates by age group, gender, and race were compared to national rates. A total of 699 pedestrians were involved in motor vehicle crashes in 2014—an average of two EMS transports each day. The distribution of injuries throughout the city did not coincide with population or income distributions, indicating there was not a consistent correlation between areas of concentrated population or concentrated poverty and areas of concentrated pedestrian injury. Twenty percent (n=138) of all injuries occurred among children age ≤14, and 22% (n=73) of severe injuries occurred among young children. The rate of injury in this age group was five times the national rate. Injury rates for adults ≥65 were less than the national average. As the urban landscape and associated pedestrian behavior transform, continued investigation of local pedestrian injury trends and evolving public health prevention strategies are necessary for ensuring pedestrian safety.

Keywords: pedestrian injury, safety, descriptive epidemiology, injury surveillance

INTRODUCTION

Pedestrian fatalities nationwide have increased over the last five years (National Center for Statistics and Analysis, 2016). Studies examining this increase have been focused at the national level, and localized studies of pedestrian injury have been scarce. Data on national trends in pedestrian injury are useful for focusing research questions and identifying risk groups for directed inquiry; however, they may incorrectly characterize risk factors unique to specific metropolitan areas. For example, a study of pedestrian fatality in Atlanta found that Hispanics had more than twice the risk of pedestrian fatality compared to the national fatality risk among Hispanics, and older adults had significantly lower fatality risk compared to their national counterparts (Beck et al., 2007).

Aside from a handful of studies on specific groups at high risk for pedestrian injury, including children under age 14 (DiMaggio & Durkin, 2002) and older adults over age 65 (Nicaj et al., 2006), and several studies investigating predictors of injury severity (Mohamed et al., 2013; Moudon et al., 2011; Pour-Rouholamin & Zhou, 2016), few studies have explored local trends in pedestrian injury (Beck et al., 2007; Pollack et al., 2014). We could find no studies in the peer-reviewed literature that provided a description of pedestrian injury localized to a specific city or region in the United States using data collected within the past 10 years. Urban areas are particularly dangerous for pedestrians as almost 80% of pedestrian fatalities nationally occurred in urban environments in 2014 (National Center for Statistics and Analysis, 2016). Paradoxically, denser and more urbanized areas reduce injury severity and crash fatality risk as pedestrians are more numerous and vehicle speeds are lower (Clifton et al., 2009; Ewing & Dumbaugh, 2009; Mohamed et al., 2013; Moudon et al., 2011).

Because of the diversity of urban landscapes across the country, understanding injury trends at the local level is essential for program planning, allocation of funds for urban planning and improvement, and targeted injury prevention efforts. Considering the variety of urban landscapes, coupled with the unique safety challenges posed by urban sprawl and the growing popularity of mixed-use land developments, localized strategies to increase pedestrian safety are particularly relevant (Ewing et al., 2003; Miranda-Moreno et al., 2011; Stevenson et al., 2016).

Baltimore City is home to nearly 621,000 residents and spans 81 square miles with an average population density of 7,671.5 people per square mile—the 13th most densely populated metropolitan area in the United States (U.S. Census Bureau, 2010). In 2014, almost half of all traffic fatalities in Baltimore occurred among pedestrians—the seventh highest rate compared to 35 other metropolitan areas with populations over 500,000 (National Center for Statistics and Analysis, 2016). This is three times the national average, where 15% of traffic-related fatalities occur among pedestrians (National Center for Statistics and Analysis, 2016).

Furthermore, Baltimore neighborhood walkability scores range from 17 to 98 on a scale of 0 to 100; the score is calculated by mapping out the distance to amenities in nine different categories, including grocery stores, restaurants, banks, parks, and schools (Baltimore Neighborhood Indicators Alliance, 2016). A high walkability score signifies that daily errands can be easily performed on foot, while lower scores indicate a neighborhood's automobile dependence. The range of scores signifies a variety of urban landscapes across neighborhoods, as well as large discrepancies in availability of important amenities. Higher neighborhood walk scores are also correlated with higher volumes of pedestrians (Mooney et al., 2016). The increased burden of pedestrian injury, coupled with the diversity of urban terrains and differential access to essential resources across the city, underscores the importance of not relying on national trend data to understand the needs of an individual city's injury risk environment. Particularly in cities comparable to Baltimore, which does not have a comprehensive, up-to-date system in place to track, map, and disseminate information on pedestrian-involved crashes (City of Baltimore Department of Transportation, 2015), analysis of local pedestrian injury trends may provide important information for safety planning not captured in national data.

Because we hypothesize that Baltimore's local injury trends differ from national injury trends in significant and meaningful ways, the goal of this study is to describe the prevalence and distribution of pedestrian injury in Baltimore City. We investigate city-wide pedestrian injury trends to assess injury risk among nationally-identified risk groups, as well as identify risk groups and locations specific to Baltimore. We also investigate demographic risk factors for injury severity. Finally, we compare citywide trends to national trends to better understand Baltimore City's distinctive injury risk patterns.

METHODS

Data Sources

Pedestrian injury incidents data were gathered in real-time through emergency medical services (EMS) records collected from January 1 to December 31, 2014 (n=699). The Baltimore City Fire Department (BCFD) operates the City's EMS system, which deploys paramedics in response to all calls within the city limits (Knowlton et al., 2013). As all of Baltimore City is served by a single EMS system, these data are representative of all EMS calls for pedestrian injuries (Cusimano et al., 2010). Furthermore, paramedics on the scene confirmed that the injury was caused by a motor vehicle crash. When an emergency call was received, Dispatch administered a brief set of questions to the caller to determine the severity of the patient condition, then asked the patient's location; Dispatch then relayed the message to paramedics. Once on the scene, paramedics evaluated the patient and filled out the EMS patient report that included the code for pedestrian injury. Paramedics recorded patient-level and other incident-related data on wireless tablet computers using proprietary software that was developed in compliance with the Electronic Maryland Ambulance Information System (Knowlton et al., 2013). Patient information included demographics; destination of transport and patient disposition; patient priority; indicators of drug or alcohol use; and paramedic-reported impression of the primary injury and other health problems. Ambulances are routinely sent to precise locations of injured persons, allowing for the geographic mapping of injury events to better define high-risk locations (Cusimano et al., 2010; Ryb et al., 2007). EMS data also provide a measure of when an injury occurred in addition to the geographic location, allowing for examination of temporal variation in injury risk (Cusimano et al., 2010).

National pedestrian injury data were obtained from the Centers for Disease Control and Prevention's (CDC) publicly-available WISQARS Injury Statistics Query and Reporting System (National Center for Injury Prevention and Control, 2016). For this analysis, we used both fatal and nonfatal injury data for 2014 because we did not know patient outcome after EMS transport. Fatal injury data were collected through the CDC's National Vital Statistics System (NVSS) from local jurisdictions responsible for registration of vital events including births and deaths (National Center for Injury

Prevention and Control, 2016). Non-fatal injury data were collected from the National Electronic Injury Surveillance System (NEISS), a national probability sample of U.S. hospitals estimated from emergency department (ED) visits involving an injury associated with a consumer product—in this case, a motor vehicle (U.S. Consumer Product Safety Commission, 2016). As almost 93% (n=646) of Baltimore injured pedestrians were transported to an ED for treatment, the WISQARS data provide a similar, nationally-representative population of injured pedestrians for comparison.

We used 2010 Census population estimates for both national and Baltimore City age-, race- and gender-based population totals (U.S. Census Bureau, 2010). This research was approved by the Institutional Review Board at the Johns Hopkins Bloomberg School of Public Health.

Measures of Injury Risk Groups

The majority of patients were described by paramedics as Black, White or "Other Race," and there was scant representation of other minority groups, including Asians and Pacific Islanders. WISQARS race categories included White, Black, American Indian/Alaskan Native, Asian and Pacific Islander, and "other" (National Center for Injury Prevention and Control, 2016). To facilitate comparisons across data sets, we grouped patients into three race categories: Black, White or Other Race.

We categorized patients into four-year age groups to facilitate direct age-adjustments and comparisons with national data. We created a time of day measure classifying the time at which an EMS call was logged into one of eight three-hour time blocks to facilitate comparison against national reporting systems: Midnight to 2:59 a.m.; 3 a.m. to 5:59 a.m.; 6 to 8:69 a.m.; 9 to 11:59 a.m.; noon to 2:29 p.m.; 3 to 5:59 p.m.; 6 to

8:59 p.m.; and 9 to 11:59 p.m. We collapsed these three-hour time blocks into four time-of-day categories: Late night (midnight to 5:59 a.m.), morning (6 a.m. to 11:59 a.m.), afternoon (noon to 5:59 p.m.) and evening (6 p.m. to 11:59 p.m.). We followed the time-based grouping definitions described by the National Highway Traffic Administration to facilitate comparisons across datasets (National Center for Statistics and Analysis, 2016). We also used the call date to categorize each injury by day of the week and season. Winter included the months of January, February and December; Spring months were from March to May; Summer was from June to August; and Fall was from September to November (National Center for Statistics and Analysis, 2016).

Measures of Injury Severity

Because we do not know patient disposition or outcome after EMS transport, we created a measure of injury severity by recoding the EMS patient priority into two severity levels (Marcin & Pollack, 2002). The purpose of EMS field triage is to transport patients to an appropriate ED equipped to treat their condition as quickly as possible (Maryland Institute for Emergency Medical Services Systems, 2015). While priority codes do not describe an injury in detail, they provide insight into the acuteness of an injury (Marcin & Pollack, 2002). Priority level 1—defined as "Critically ill or injured person requiring immediate attention; unstable patients with life-threatening injury or illness"—and priority level 2—defined as "Less serious condition yet potentially life-threatening injury or illness, requiring emergency medical attention but not immediately endangering the patient's life"— were classified as the most severe injuries. Priority 3, defined as "Non-emergent condition, requiring medical attention but not on an emergency basis," was classified as less severe injuries. To determine injury severity for patients labeled Priority 4 (n=6), "Does not require medical attention," we used the "patient disposition" description provided by the paramedic at the scene. Patients who were dead at the scene (n=4) were reclassified to the most severe injury category. Two patients labeled Priority 4 were treated and transported to an ED; these patients were categorized as less severely injured. Definitions of priority levels were taken from the Maryland Medical Protocols for Emergency Medical Services Providers (Maryland Institute for Emergency Medical Services Systems, 2015). We used the "patient disposition" description for three patients who had missing priority codes. Two patients were described as "no treatment required" and were classified as having less severe injuries. One patient refused care and was, consequently, excluded from severity analysis as injury severity could not be determined.

Data Analysis

Locations of pedestrian injuries were geocoded and mapped using ArcGIS 10.4. This provided a visual representation of the distribution of pedestrian injury and allowed for visual comparison of this distribution against potential risk factors such as population density and income distributions. Population density was calculated by taking the total population of each Census block group and dividing by the area of the block group in square miles.

We used Pearson Chi-square Test of Independence to investigate differences in severity level across the risk groups as defined above. We also performed post hoc testing on statistically significant measures with more than two categories to determine which cells contributed most to a statistically significant omnibus test (Beasley & Schumacker, 1995).

Unadjusted pedestrian injury rates by age group, gender, and race for Baltimore were compared to national pedestrian injury rates (fatal and non-fatal combined). Rates represent the count of pedestrian injuries for Baltimore and the nation, respectively, divided by the total population for each age, gender and race group for Baltimore and the nation. Population counts stratified by demographic group were taken from the 2010 Census (U.S. Census Bureau, 2010). We performed direct age, gender, and race adjustments for Baltimore rates to account for differences in city and national population distributions and to facilitate comparisons. We also calculated Pearson Chi-Square Tests of Independence, comparing observed incidence of pedestrian injury with expected counts of injury using national injury rates (fatal and non-fatal combined). Analyses were performed using SPSS 20.

RESULTS

A total of 699 pedestrians were involved in motor vehicle crashes in 2014—an average of two EMS transports for injured pedestrians each day (Table 3.1). The mean age of injured pedestrians was 32.7 (sd=18.6), slightly younger than the national average of 37 years (National Center for Statistics and Analysis, 2016). The majority of injured pedestrians were men (n=435, 62.2%), and almost three-quarters of injured pedestrians were Black (n=421), where race was recorded. Race category was missing for 17.9% (n=124) of Baltimore pedestrians and 23.2% (n=45,180) of national pedestrians. A quarter of injuries occurred from 3 p.m. to 5:59 p.m. (n=164), over 15% occurred on Friday (n=114), and almost a third occurred in the fall (n=205). The most frequently occurring day and time for injuries was Friday from 3 to 5:59 p.m. (n=35, 5.0%). Drug and alcohol use indicators were recorded for only 23% (n=163) of patients; positive indicators of substance use were present in a quarter of patients (n=40) when it was noted at all.

The downtown neighborhood had the largest number of injuries; the two adjoining block groups which make up the downtown district contained 36 and 13 injuries, respectively (Figure 3.1). The next largest area of injuries was in the northwest quadrant of the city in the Reisterstown Station neighborhood with 10 injuries. Three other block groups, located across the city, had eight injuries. The distribution of injuries throughout the city did not coincide with population density or income distributions. In other words, there was not a consistent correlation between areas of concentrated population or concentrated poverty and areas of concentrated pedestrian injury.

Men suffered significantly more severe injuries than women ($p=0.008$) (Table 3.2). Time of day was also a significant predictor of severity, with injuries occurring in the evening significantly more likely to result in a severe injury and injuries occurring in the morning significantly less likely to result in a severe injury ($p<0.001$). Where drug and alcohol use indicators were recorded, patients with no indicators of substance use were significantly less likely to be severely injured ($p=0.008$). Over 70% (n=198) of severely injured pedestrians were Black, but differences among racial groups were not statistically significant ($p=0.083$).

Twenty percent (n=138) of all injuries occurred among children age 14 and younger, and 22% (n=73) of severe injuries occurred among children in this age group (Table 3.2). Almost 61% of injuries of children age 14 and younger were among boys (n=84), and 65.8% (n=48) of severe injuries among children were among boys (Table 3.3). Half of all injuries (n=69) and half of severe injuries (n=36) occurred in the afternoon.

Almost 72% of all injured children were Black (n=99), and almost 89% of severely injured children were Black (n=55); this difference was not significant.

Less than five percent (n=32) of all injuries occurred among older adults age 65 or older (Table 3.1). Among severely injured pedestrians, older adults made up only 3.6% of cases (n=12) (Table 3.2). Injuries among seniors were relatively evenly split between men and women for all injuries and for severe injuries (Table 3.3). Forty percent of all injuries (n=13) and half of severe injuries (n=6) occurred in the afternoon. Almost half (n=15) of all injuries and 46% (n=5) of severe injuries among older adults occurred among Blacks; this difference was not significant.

Baltimore City's age-adjusted pedestrian injury rate is 1.13 per 1,000 population, almost twice the national rate of 0.61 per 1,000 (Table 3.4). Observed rates of pedestrian injuries for almost every age group were significantly larger than what would be expected if Baltimore's injury rates were comparable to national rates; age groups over 75 years were similar to expected counts. Observed injury rates were also significantly greater for all sex and race groups ($p<0.0001$). This difference was particularly pronounced among children aged 0 to 14 years, where the age-adjusted rate for this age group of 1.30 per 1,000 population was almost five times greater than the national average of 0.27 per 1,000 (Table 3.5). The sex-adjusted rate of 1.14 per 1,000 population was also substantially greater than the national average of 0.45 per 1,000—a difference in magnitude of 2.5 times.

DISCUSSION

This study provides a description of the distribution of pedestrian injury localized to one metropolitan area and identifies unique demographic and geographic risk groups; it also demonstrates how national trend data may not accurately represent local pedestrian injury trends. Comparing Baltimore City injury trends to national trends revealed several important discrepancies, both in risk groups and risk locations. The downtown neighborhood—the most walkable Baltimore neighborhood with a Walk Score of 98 (Baltimore Neighborhood Indicators Alliance, 2016)—reported the highest number of pedestrian injuries. This is unsurprising as the convergence of people and vehicles at popular destinations such as workplaces, restaurants, bars, and recreation and entertainment venues may provide more opportunities for pedestrians and vehicles to interact, increasing crash risk (Dai et al., 2010). However, the distribution of injuries throughout the city did not coincide with population distribution, suggesting that neighborhood risk for pedestrian injury was not related to population density. These findings are supported by several studies which associated densely-populated urban areas with decreased pedestrian injury risk and severity. A review of urban planning studies for traffic safety found that densely-populated urban areas are characterized by roadway designs that hinder traffic flow and reduce vehicle speeds, such as narrow lanes and traffic-calming infrastructure (Ewing & Dumbaugh, 2009). Consequently, dense urban areas were safer for pedestrians than lower traffic volume suburban regions as fewer miles per capita were driven in urban areas, and driving is done at consistently lower speeds that are less likely to produce pedestrian-involved crashes (Ewing & Dumbaugh, 2009). A comparative analysis of pedestrian injury fatality risk in New York and Montreal also found that built environment features related to denser and more urbanized areas with lower vehicle speeds reduced crash fatality risk (Mohamed et al., 2013). Further inquiry into the local streetscape and other possible pedestrian injury risk factors is needed to understand why the downtown region experiences a high number of pedestrian injuries.

Pedestrian injuries in Baltimore are more likely to occur in the afternoon in the hours directly after school dismissal, in contrast to national injury patterns where pedestrian injuries are more likely to occur after dark (National Center for Statistics and Analysis, 2016). This finding is echoed in the overrepresentation of children under age 14, amongst whom half of all injuries occurred in the afternoon. DiMaggio and colleagues (2002) found similar injury patterns in their study of pedestrian injury among young children in New York City.

Despite similar population distributions for children under age 14, the Baltimore childhood injury rate is five times the national average. Road crossing is a complex behavior, and preadolescent children lack the cognitive ability to make well-planned crossing decisions, resulting in higher injury rates among children (Retting et al., 2003; Stavrinos et al., 2009). In urban areas, walking may be a more common mode of transportation for children, especially in families that do not own cars (Durkin et al., 1999). Thirty percent of Baltimore households on average did not have access to a car for personal use in 2014; in some neighborhoods this percentage was as high as 72% (Baltimore Neighborhood Indicators Alliance, 2016). Black children are more likely to live farther distances from school than White children, which could account for increased injury rates among children and which may explain why almost three-quarters of injured children were Black (Cottrill & Thakuriah, 2010; Steinbach et al., 2010). Furthermore, children's behavior, such as emerging from between parked cars, playing in the street, and "dart and dash" crossing, may add to increased crash rates (DiMaggio & Durkin, 2002), although those data were not available in this study.

The overrepresentation of Blacks among injured pedestrians in general, and children in particular, was not attributable to population distribution alone as the race-adjusted injury rate was almost twice the national average. Our findings are comparable to previous studies which observed that minority groups were at higher risk for pedestrian injury (Laflamme & Diderichsen, 2000; Loukaitou-Sideris et al., 2007; Ryb et al., 2007) and fatality (Beck et al., 2007; Campos-Outcalt et al., 2002) compared to their White counterparts. It is possible that Blacks in Baltimore are more likely to walk or take public transportation than other groups, resulting in greater exposure to street danger and increased injury risk (Cottrill & Thakuriah, 2010; Loukaitou-Sideris et al., 2007). To date, conclusive evidence explaining minority children's higher pedestrian injury rates has yet to be determined (Steinbach et al., 2010, 2016).

While the age-adjusted rate of injuries for older adults was elevated compared to the national rate, older adults did not make up a substantial portion of injured pedestrians. Adults age 65 and older made up less than 5% of injured pedestrians—less than the national average of 11% for all injured pedestrians (National Center for Statistics and Analysis, 2016). Older adults also made up a small proportion of severe injuries. Less than 4% of severe injuries occurred in this age group in Baltimore, while 38% of pedestrian deaths in New York City occurred among older adults (Nicaj et al., 2006). This discrepancy is surprising as seniors make up a similar percent of the total population of each city (U.S. Census Bureau, 2010). It is possible that older adults in Baltimore are less mobile than comparable adults in New York City, and consequently have fewer opportunities to come into contact with traffic. Older adults in Baltimore may also be more vigilant. A Maryland study found that older adults living in urban areas considered themselves at increased risk for pedestrian injury and were more observant of traffic safety procedures than their suburban or ex-urban counterparts (Reed & Sen, 2005).

Limitations

This study is cross-sectional and, therefore, does not allow for discussion of changes in the injury risk environment over time. Because we could not link EMS data with hospital data, we were unable to track what happened to the pedestrian after transport to the ED; consequently, this study does not discuss pedestrian fatality in particular but pedestrian injury in general. Demographic features were recorded based on EMS staff perception and not based on self-report by the patient; it is possible that certain demographic characteristics such as sex or race were mislabeled. Race category was missing from approximately one-fifth of the Baltimore and national populations. It is possible that these pedestrians were different from their counterparts in meaningful or systematic ways, biasing our conclusions regarding injury rates for racial groups.

We did not have access to a description of the circumstances surrounding each injury, limiting our ability to draw conclusions about injury mechanisms or make recommendations for targeted injury prevention strategies. Police accident reports have been commonly used in previous pedestrian injury studies to identify crash characteristics and risk factors (Clifton et al., 2009; DiMaggio & Durkin, 2002; Mohamed et al., 2013; Nicaj et al., 2006; Pour-Rouholamin & Zhou, 2016). However, a San Francisco study found that the Statewide Integrated Traffic Reporting System compiled by California Highway Patrol under-reported pedestrian injuries among Blacks and men, as well as less severe injuries (Sciortino et al., 2005). Paramedics are not required to alert police when they treat a person struck by a motor vehicle; some pedestrians may be reluctant to summon police and file a report when the police are not initially present at the scene of a crash (Sciortino et al., 2005). It is possible that EMS records could be more complete for a wider range of injuries, as well as injuries which occur among certain minority groups, compared to police reports. EMS data have been used in previous analyses of non-violent injuries (Newgard et al., 2011; Warden et al., 2010). Furthermore, previous studies have shown that the majority of pedestrians are struck within a mile of their home (Anderson et al., 2012; Haas et al., 2015), suggesting that injured pedestrians are representative of the neighborhoods in which they are struck.

Conclusion

While national trends in pedestrian injury are useful for focusing research questions and identifying risk groups for directed inquiry, they may incorrectly characterize risk factors unique to specific metropolitan areas. As the urban landscape and associated pedestrian behavior transform, continued investigation of local pedestrian injury trends and evolving public health prevention strategies are necessary for ensuring pedestrian safety. The growing popularity of mixed-use land developments, public transportation, and alternative "green" methods of transportation will continue to increase pedestrian activity and, consequently, pedestrian injury (Miranda-Moreno et al., 2011). Distractions from multimedia devices and cell phones have also created new challenges for pedestrian safety education and urban planning (Schwebel et al., 2012). In Baltimore, the need for safety strategies is particularly important as there are 25 new residential development projects underway in the downtown district alone—the neighborhood with the highest pedestrian injury count (Papagani, 2016). A study of both fatal and non-fatal crashes in Baltimore found that 52% of pedestrians were culpable in the crash, compared with 36% of drivers

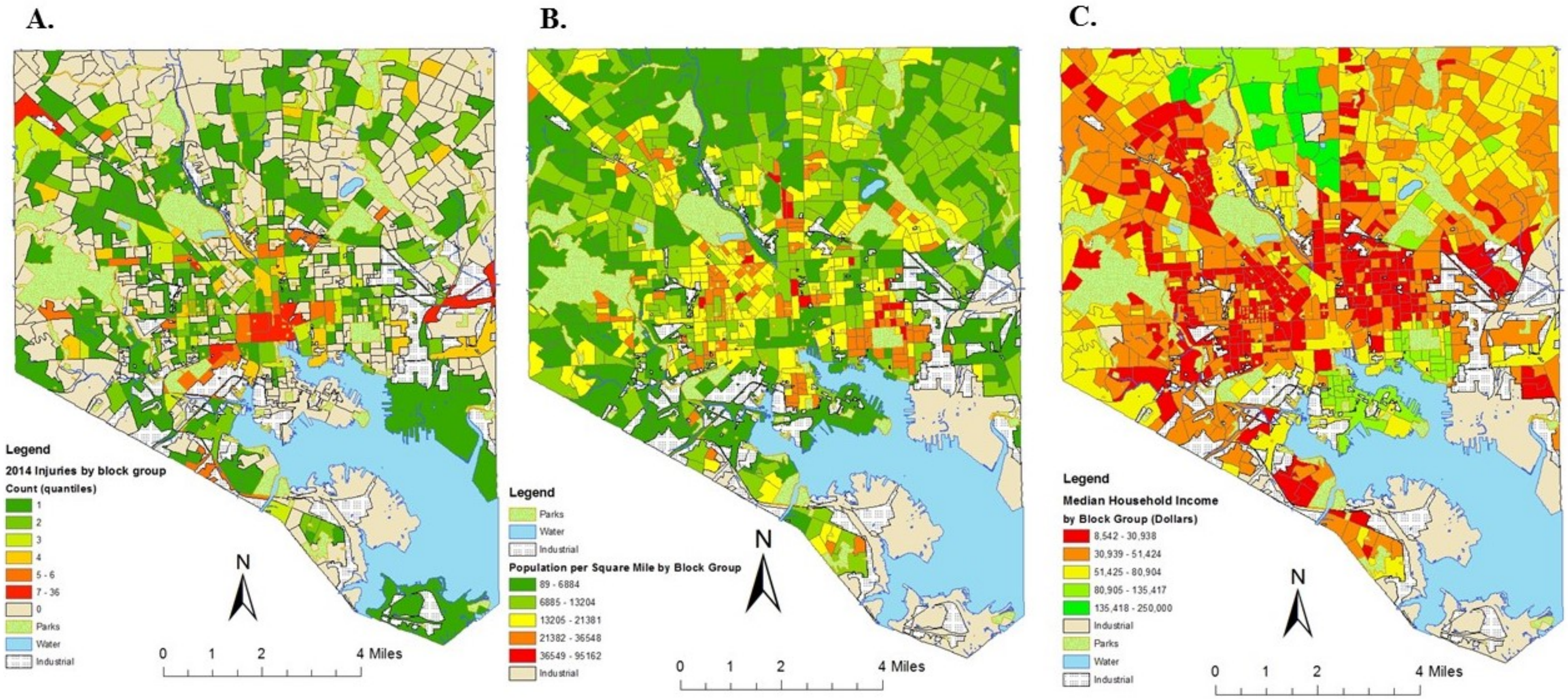
(Preusser et al., 2002). A deeper understanding of the complex mechanisms which give rise to unique local and regional risk patterns is necessary to effectively prevent future pedestrian injuries.

Table 3.1. Description of sample (n=699)

	Baltimore Pedestrian Injury Mean (sd) or N(%)
Age	32.7 (18.6)
Age groups	
0-4	20 (2.9)
5-9	51 (7.3)
10-14	67 (9.6)
15-19	65 (9.3)
20-24	78 (11.2)
25-29	73 (10.4)
30-34	56 (8.0)
35-39	34 (4.9)
40-44	49 (7.0)
45-49	43 (6.2)
50-54	65 (9.3)
55-59	37 (5.3)
60-64	29 (4.1)
65-69	15 (2.1)
70-74	9 (1.3)
75-79	6 (0.9)
80+	2 (0.3)
Sex	
Male	435 (62.2)
Female	264 (37.8)
Race (n=575)	
Black	421 (73.2)
White	123 (17.6)
Other Race	31 (4.4)
Drug and Alcohol Use Indicators (n=163)	
Indicators present	40 (24.5)
None present	98 (60.1)
Unknown	25 (15.3)
Severity of Injury (n=698)	
Life threatening or dead at scene	329 (47.1)
Less severe	369 (52.8)
Destination	
Transported to hospital	648 (92.4)
Treated and released	6 (0.9)
Refused Care	41 (5.9)
No treatment required	2 (0.3)
Dead at scene	4 (0.6)

Day of the Week	
Monday	109 (15.6)
Tuesday	98 (14.0)
Wednesday	106 (15.2)
Thursday	110 (15.7)
Friday	114 (16.3)
Saturday	93 (13.3)
Sunday	69 (9.9)
Time of Day	
Midnight to 2:59 a.m.	32 (4.6)
3 a.m. to 5:59 a.m.	14 (2.0)
6 to 8:69 a.m.	72 (10.3)
9 to 11:59 a.m.	92 (13.2)
Noon to 2:39 p.m.	106 (15.2)
3 to 5:59 p.m.	164 (23.5)
6 to 8:59 p.m.	139 (19.9)
9 to 11:59 p.m.	80 (11.4)
Season	
Winter	147 (21.0)
Spring	182 (26.0)
Summer	165 (23.6)
Fall	205 (29.3)

Figure 3.1. Distribution of pedestrian injuries, population density, and income for Baltimore City



Map A: Count of pedestrian injuries from January 1 to December 31, 2014, by Census block group (Data Source: Baltimore City Fire Department)
Map B: Total population divided by the area of the Census block group in square miles (Data Source: 2010 U.S. Census)
Map C: Median household income by Census block group (Data Source: 2010 U.S. Census)

Table 3.2. Characteristics of pedestrian injuries stratified by injury severity (n=698)

	Severity Level		
Characteristic	Life Threatening/DOA n (%) (n=329)	Not Severe n (%) (n=369)	p-value
Age groups			0.689*
0-4	12 (3.6)	8 (2.2)	
5-9	27 (8.2)	24 (6.5)	
10-14	34 (10.3)	33 (8.9)	
15-19	26 (7.9)	39 (10.6)	
20-24	33 (10.0)	45 (12.2)	
25-29	34 (10.3)	38 (10.3)	
30-34	26 (7.9)	30 (8.1)	
35-39	16 (4.9)	18 (4.9)	
40-44	22 (6.7)	27 (7.3)	
45-49	21 (6.4)	22 (6.0)	
50-54	38 (11.6)	27 (7.3)	
55-59	15 (4.6)	22 (6.0)	
60-64	13 (4.0)	16 (4.3)	
65-69	4 (1.2)	11 (3.0)	
70-74	3 (0.9)	6 (1.6)	
75-79	4 (1.2)	2 (0.5)	
80+	1 (0.3)	1 (0.3)	
Age 0-14	73 (22.2)	65 (17.6)	0.130
Age 65+	12 (3.6)	20 (5.4)	0.264
Race (n=574)			0.083
Black	198 (71.5)	222 (74.7)	
White	58 (20.9)	65 (21.9)	
Other Race	21 (3.7)	10 (3.4)	
Sex			0.008
Male	222 (67.5)	213 (57.7)	
Female	107 (32.5)	156 (42.3)	
Drug & Alcohol Use Indicators (n=162)			0.008
Indicators present	28 (31.8)	12 (3.3)	
None present	43 (48.9)ǂ	54 (73.0)ǂ	
Unknown	17 (19.3)	8 (2.2)	
Day of week			0.289
Monday	46 (14.0)	63 (17.1)	
Tuesday	50 (15.2)	48 (13.0)	
Wednesday	58 (17.6)	48 (13.0)	
Thursday	48 (14.6)	62 (16.8)	
Friday	58 (17.6)	55 (14.9)	
Saturday	42 (12.8)	51 (13.8)	
Sunday	27 (8.2)	42 (11.4)	
Time of Day**			<0.001
Late Night	25 (7.6)	21 (5.7)	
Morning	53 (16.1)ǂ	110 (29.8)ǂ	
Afternoon	128 (38.9)	142 (38.5)	
Evening	123 (37.4)ǂ	96 (26.0)ǂ	

Characteristic	**Severity Level**		p-value
	Life Threatening/DOA n (%) (n=329)	Not Severe n (%) (n=369)	
Season			0.098
Winter	58 (17.6)	88 (23.8)	
Spring	86 (26.1)	96 (26.0)	
Summer	89 (27.1)	76 (20.6)	
Fall	96 (29.2)	109 (29.5)	

ǂ Statistically significant compared to Bonferroni-corrected p-value

*1 or more cells has expected count less than 5

**Late night consisted of the hours from midnight to 5:59 a.m.; Morning from 6 a.m. to 11:59 a.m.; Afternoon from noon to 5:59 p.m.; Evening from 6 p.m. to 11:59 p.m.

Table 3.3. Characteristics of injured pedestrians for specific risk groups

Characteristic	Life Threatening/Dead n (%)	Not Severe n (%)	Total	p-value
Age 0-14 years (n=138)				
Race (n=112)				0.140*
Black	55 (88.7)	44 (88.0)	99 (71.7)	
White	2 (3.2)	5 (10.0)	7 (5.1)	
Other Race	5 (8.1)	1 (2.0)	6 (4.3)	
Sex				0.213
Male	48 (65.8)	36 (55.4)	84 (60.9)	
Female	25 (34.2)	29 (44.6)	54 (39.1)	
Time of Day**				0.792*
Late Night	0 (0.0)	0 (0.0)	0 (0.0)	
Morning	10 (13.7)	11 (16.9)	21 (15.2)	
Afternoon	36 (49.3)	33 (50.8)	69 (50.0)	
Evening	27 (37.0)	21 (32.3)	48 (34.8)	
Day of week				0.412
Monday	10 (13.7)	10 (15.4)	20 (14.5)	
Tuesday	13 (17.8)	8 (12.3)	21 (15.2)	
Wednesday	17 (23.3)	8 (12.3)	25 (18.1)	
Thursday	6 (8.2)	9 (13.8)	15 (10.9)	
Friday	12 (16.4)	9 (13.8)	21 (15.2)	
Saturday	10 (13.7)	13 (20.0)	23 (16.7)	
Sunday	5 (6.8)	8 (12.3)	13 (9.4)	
Season				0.181
Winter	7 (9.6)	11 (16.9)	18 (13.0)	
Spring	27 (37.0)	14 (21.5)	41 (29.7)	
Summer	18 (24.7)	16 (24.6)	34 (24.6)	
Fall	21 (28.8)	24 (36.9)	45 (32.6)	
Age 65 years and older (n=32)				
Race (n=26)				0.198*
Black	5 (45.5)	10 (66.7)	15 (57.7)	
White	4 (36.4)	5 (33.3)	9 (34.6)	
Other Race	2 (18.2)	0 (0.0)	2 (7.7)	
Sex				0.515*
Male	8 (66.7)	11 (55.0)	19 (59.4)	
Female	4 (33.3)	9 (45.0)	13 (40.6)	
Time of Day**				0.636*
Late Night	0 (0.0)	0 (0.0)	0 (0.0)	
Morning	3 (25.0)	8 (40.0)	11 (34.4)	
Afternoon	6 (50.0)	7 (35.0)	13 (40.6)	
Evening	3 (25.0)	5 (25.0)	8 (25.0)	

Characteristic	Life Threatening/Dead n (%)	Not Severe n (%)	Total	p-value
Day of week				0.769*
Monday	0 (0)	2 (10.0)	2 (6.2)	
Tuesday	1 (8.3)	2 (10.0)	3 (9.4)	
Wednesday	4 (33.3)	3 (15.0)	7 (21.9)	
Thursday	3 (25.0)	4 (20.0)	7 (21.9)	
Friday	2 (16.7)	3 (15.0)	5 (15.6)	
Saturday	2 (16.7)	5 (25.0)	7 (21.9)	
Sunday	0 (0)	1 (5.0)	1 (3.1)	
Season				0.088*
Winter	3 (25.0)	4 (20.0)	7 (21.9)	
Spring	0 (0)	7 (35.0)	7 (21.9)	
Summer	2 (16.7)	4 (20.0)	6 (18.8)	
Fall	7 (58.3)	5 (25.0)	12 (37.5)	

*1 or more cells has expected count less than 5

**Late night consisted of the hours from midnight to 5:59 a.m.; Morning from 6 a.m. to 11:59 a.m.; Afternoon from noon to 5:59 p.m.; Evening from 6 p.m. to 11:59 p.m.

Table 3.4. Comparison of Baltimore pedestrian injury rates to national rates for 2014

Groups	Baltimore City			National			p-value***
	Injuries	Pop**	Unadjusted Rate (per 1,000)	Injuries*	Population**	Rate (per 1,000)	
Total injuries (fatal and non-fatal)	699	620,961	1.13	194,807	318,857,056	0.61	<0.001
Age group							
0-4 years	20	41,152	0.49	1,999	19,876,883	0.10	<0.0001ǂ
5-9 years	51	35,441	1.44	6,088	20,519,566	0.30	<0.0001
10-14 years	67	34,339	1.95	8,562	20,671,506	0.41	<0.0001
15-19 years	65	44,278	1.47	15,346	21,067,647	0.73	<0.0001
20-24 years	78	56,460	1.38	19,567	22,912,174	0.85	<0.0001
25-29 years	73	57,675	1.27	12,159	21,987,938	0.55	<0.0001
30-34 years	56	45,889	1.22	11,755	21,528,566	0.55	<0.0001
35-39 years	34	37,675	0.90	10,206	19,921,650	0.51	0.0006
40-44 years	49	38,999	1.26	10,018	20,591,483	0.49	<0.0001
45-49 years	43	43,572	0.99	9,040	20,888,042	0.43	<0.0001
50-54 years	65	43,873	1.48	12,617	22,570,809	0.56	<0.0001
55-59 years	37	37,978	0.97	8,725	21,511,449	0.41	<0.0001
60-64 years	29	30,928	0.94	7,051	18,566,132	0.38	<0.0001
65-69 years	15	22,098	0.68	5,484	15,325,266	0.36	0.0133
70-74 years	9	16,454	0.55	3,270	11,073,024	0.30	0.0736
75-79 years	6	13,397	0.45	2,456	7,922,324	0.31	0.3172ǂ
80-84	1	10,513	0.10	1,929	5,760,366	0.33	0.1335ǂ
85+	1	10,350	0.10	1,214	6,162,231	0.20	0.4795ǂ
By race****							
White	123	188,380	0.65	81,611	201,048,793	0.41	<0.0001
Black	421	392,312	1.07	41,697	44,309,394	0.94	0.0068
Other Race	42	40,269	1.04	26,319	73,498,869	0.36	<0.0001
By gender							
Male	435	292,249	1.49	81,251	156,936,487	0.54	<0.0001
Female	264	328,712	0.80	61,371	161,920,569	0.39	<0.0001

*Data combines both fatal and non-fatal injuries. Obtained from Centers for Disease Control and Prevention, National Center for Injury Prevention and Control, Division of Analysis, Research, and Practice Integration. http://www.cdc.gov/injury/wisqars/

**Data taken from 2010 U.S. Census

***Pearson Chi-square test comparing observed incidence of pedestrian injury with expected counts using national injury rates

****Race not stated in 124 of Baltimore City injury cases and 45,180 of national injury cases

ǂ1 cell has expected count less than 5

Table 3.5. Unadjusted and adjusted rates of pedestrian injuries in Baltimore and the United States for 2014

Characteristic	Baltimore		National*	Magnitude of difference between adjusted and national rates
	Unadjusted Rate (per 1,000)	Adjusted Rate** (per 1,000)	Rate (per 1,000)	
All Age Groups	1.13	1.11	0.61	1.82
Age 0-14	3.89	1.30	0.27	4.81
Age 15-29	3.83	1.37	0.71	1.93
Age 65+	0.44	0.46	0.31	1.48
Race	0.94	0.80	0.47	1.70
Sex	1.13	1.14	0.45	2.53

*Data combines both fatal and non-fatal injuries. Obtained from Centers for Disease Control and Prevention, National Center for Injury Prevention and Control, Division of Analysis, Research, and Practice Integration. http://www.cdc.gov/injury/wisqars/

**Direct adjustment using population distribution of indicated demographic group from 2010 U.S. Census

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CHAPTER 4. NOVEL METHODS FOR ENVIRONMENTAL ASSESSMENT OF PEDESTRIAN INJURY: CREATION & VALIDATION OF THE INVENTORY FOR PEDESTRIAN SAFETY INFRASTRUCTURE

ABSTRACT

Nationally, 80% of pedestrian fatalities nationally occurred in urban environments, yet several studies show that denser and more urbanized areas reduce injury severity and crash fatality risk. Identifying street-level risk factors for pedestrian injury is essential for urban planning and improvement projects, as well as targeted injury prevention efforts. Yet creating and maintaining a comprehensive database of a city's traffic safety infrastructure can be cumbersome and costly. The purpose of this study was to create and validate a neighborhood environmental observational assessment tool to capture evidence-based pedestrian safety infrastructure using Google Street View (GSV)—The Inventory for Pedestrian Safety Infrastructure (IPSI). We collected measures in-person at 172 liquor stores in Baltimore City from June to August 2015 to assess the tool's reliability; we then collected IPSI measures at the same 172 locations using GSV from February to March 2016 to assess IPSI reliability using GSV. The majority of items had good or excellent levels of inter-rater reliability (ICC≥0.8), with intersection features showing the highest agreement across raters. Two scales were also developed using Exploratory Factor Analysis, and both showed strong internal consistency (Cronbach's alpha ≥0.6). The IPSI provides a valid, economically-efficient tool for assessing pedestrian safety infrastructure that can be employed for a variety of research and urban planning needs. It can also be used for in-person or GSV observation. Reliable and valid measurement of pedestrian safety infrastructure is essential to effectively prevent future pedestrian injuries.

Keywords: pedestrian injury, infrastructure, environmental observation, Google Street View

INTRODUCTION

Nationally, 15% of traffic-related fatalities occur among pedestrians, and urban areas are particularly dangerous as almost 80% of pedestrian fatalities nationally occurred in urban environments in 2014 (National Center for Statistics and Analysis, 2016). Yet several studies have demonstrated that denser and more urbanized areas reduce injury severity and crash fatality risk as pedestrians are more numerous and vehicle speeds are lower (Clifton et al., 2009; Ewing & Dumbaugh, 2009; Mohamed et al., 2013; Moudon et al., 2011).

A better understanding of the street environment could help elucidate the antecedents of the high fatality rate in urban areas. However, street landscapes vary between neighborhoods and between cities, and creating and maintaining a comprehensive database of a city's traffic safety infrastructure can be cumbersome and costly (Mooney et al., 2016; Rundle et al., 2011). Strategies for increasing pedestrian safety with a localized focus are particularly relevant considering the variety of urban landscapes, coupled with the unique safety challenges posed by urban sprawl and the growing popularity of mixed-use land developments (Ewing et al., 2003; Miranda-Moreno et al., 2011; Stevenson et al., 2016). Identifying street-level risk factors for pedestrian injury is essential for urban planning and improvement projects, as well as targeted injury prevention efforts.

In Baltimore City, the need for pedestrian safety strategies is particularly relevant as intensifying residential development, coupled with improved transportation networks and alternative "green" transportation methods, increase pedestrian activity and, consequently, pedestrian injury (Miranda-Moreno et al., 2011; Papagani, 2016). In 2014, almost half of all traffic fatalities in Baltimore City occurred among pedestrians—the seventh highest rate compared to 35 other metropolitan areas with populations over 500,000—and Baltimore averages two EMS transports daily for pedestrian-involved traffic accidents (National Center for Statistics and Analysis, 2016). Yet no comprehensive database cataloging the city's traffic safety infrastructure exists, in part because of the logistical and methodological challenges of maintaining such a database (City of Baltimore Department of Transportation, 2015; Mooney et al., 2016; Rundle et al., 2011). Consequently, the need for an inexpensive, easy to use, evidence-based tool to assess the presence (or absence) of pedestrian safety infrastructure arose. The purpose of this study was to create and validate a neighborhood environmental observational assessment tool to capture evidence-based pedestrian safety infrastructure using Google Street View—The Inventory for Pedestrian Safety Infrastructure (IPSI).

Neighborhood environmental audits are a form of Systematic Social Observation, a standardized method for directed observation of the physical, social, and economic characteristics of neighborhoods (Sampson & Raudenbush, 1999). Trained researchers record indicators of neighborhood characteristics using a standardized assessment tool and following a prescribed data collection protocol. However, these neighborhood assessments are time-consuming and expensive and, consequently, tend to be limited in their geographic scope (Bader et al., 2015; Clarke et al., 2010; Rundle et al., 2011). Google Street View (GSV) provides an alternative to in-person observation. GSV is a free tool offering panoramic, street-level images of city streets across the world; the user types in an address and can virtually "walk" forward or backward along a street, revolve 360 degrees, rotate vertically 290 degrees, and zoom in and out (Clarke et al., 2010; Rundle et al., 2011). GSV images are also time-stamped with the month and year an image was processed, and many locations allow the user to travel back in time to every previous image taken at a location; this allows for the comparisons of neighborhood features over time. Performing street audits with GSV allows for a large amount of data collection in a shorter period of time. One study of 850 intersections estimated that using GSV in place of in-person audits cut down data collection time from three person-years to one-person month (Koepsell et al., 2002; Mooney et al., 2016). GSV has already been used successfully to audit a variety of urban environments and characteristics, including physical disorder (Bader et al., 2015; Less et al., 2015; Mooney et al., 2014; Odgers et al., 2012), parks and greenspace (Taylor et al., 2011), the local food environment (Clarke et al., 2010), and support for physical activity (Ben-Joseph et al., 2013; Griew et al., 2013; Kelly et al., 2013; Vanwolleghem et al., 2014). GSV has also been used previously to assess environmental contributions to traffic-related injuries (Mooney et al., 2016; Rundle et al., 2011).

Previous environmental observation tools which have been used to examine traffic safety infrastructure were not designed specifically for pedestrian safety. Many of these tools focus on environmental features which promote physical activity or walkability such as street slope or perceived attractiveness of the street environment (Clifton et al., 2007; Griew et al., 2013; Kelly et al., 2013; Nickelson et al., 2013; Pikora et al., 2002) or include traffic calming measures that are not necessarily protective of pedestrians (Clarke et al., 2010; Day et al., 2006; Mooney et al., 2016). While many of these roadway features may be beneficial to pedestrians (e.g., traffic calming features such as chockers and chicanes), the inclusion of these measures is not reliant on evidence from studies which examine best practices for pedestrian safety; furthermore, physical environment features which are instrumental in predicting pedestrian safety may be overlooked (Nickelson et al., 2013).

Previous studies which have attempted to assess pedestrian safety have also limited their scope to crash risk at intersections and have largely overlooked other roadway safety infrastructure (Asadi-Shekari et al., 2015). Measures for IPSI were selected based on several studies of accident-reduction infrastructure improvements.

Furthermore, most observational assessments rely on systematic sampling of block faces to obtain an overall representation of neighborhood characteristics (Bader et al., 2015; Day et al., 2006; Furr-Holden et al., 2008; Odgers et al., 2012). To our knowledge, no observational assessment tool has examined the neighborhood environment at the location of a specific event such as a traffic accident or neighborhood feature such as a playground or corner store. We tested the IPSI at locations of alcohol outlets in Baltimore City. Excessive alcohol consumption is a leading contributor to pedestrian injury and fatality in the United States (National Center for Statistics and Analysis, 2016), and neighborhood presence of alcohol outlets significantly increases pedestrian injury risk (DiMaggio et al., 2016; Schuurman et al., 2009). As little research exists which conceptualizes the mechanisms by which alcohol outlets impact pedestrian injury risk, a better understanding of pedestrian safety infrastructure around alcohol outlets may shed light on how alcohol outlets affect pedestrian injury risk.

METHODS

Tool Development

We examined the existing literature on road safety design to promote pedestrian safety (Asadi-Shekari et al., 2015; Gandhi & Trivedi, 2007; Gitelman et al., 2012; Retting et al., 2003) and pedestrian-involved accident analysis (Ewing & Dumbaugh, 2009; Lee &

Abdel-Aty, 2005), as well as recommendations from the Federal Highway Administration (Campbell et al., 2004; Nabors et al., 2008), technical guides for pedestrian safety (Institute of Transportation Studies, 2013), and subject-matter experts, to develop a comprehensive a list of evidence-based protective and exposing pedestrian safety infrastructure for an urban environment. We subdivided this list into roadway features, midblock features and intersection features to facilitate coding (Table 4.1). As the purpose of this study was to capture pedestrian safety infrastructure, we did not include measures on traffic or pedestrian volume or average vehicle speed. We conceptualized the IPSI as incorporating the principles set forth in Haddon's Countermeasures, and we posit that infrastructure impacts pedestrian safety based on the principles described in the social-ecological model (Haddon, 1973; McLeroy et al., 1988; Runyan, 2003).

We then created a protocol to best capture the risk environment surrounding a specific location. As most observational assessment studies divide neighborhoods into discrete block faces, this technique was not appropriate for this study as a location of interest could be at an intersection or mid-block. A mid-block incident could be examined using the traditional block-face method, but an intersection would require the examination of two connecting block faces. Consequently, we developed a new technique to assess the pedestrian safety risk environment without stratifying by midblock or intersection. At each location, we measured intersection features, roadway features, and midblock features; however, for stores located on a corner, we collected a second measure for roadway features and midblock features for the intersecting street (Figure 4.1). We pilot tested the instrument on 30 alcohol outlets in two neighborhoods in East and West Baltimore and corrected it for clarity and reproducibility.

In-Person Data Collection

In-person street observation occurred from June to August 2015 as part of a larger study of alcohol outlets in Baltimore City; the goal of this parent study was to identify characteristics of liquor stores related to compliance and targets of future policies to reduce the public health impact of liquor stores on communities. Data on the location and license types of all establishments licensed to sell alcohol in Baltimore City were obtained from the Board of Liquor License Commissioners for Baltimore City. There are 12 liquor license types administered by the Board. This study focused on the four licensure classes concerned with sale of package goods for off-premise consumption—liquor packaged goods stores, bars/taverns, and wine and beer only stores (n=685). On- and off-premise outlets differentially impact injury risk. Off-premise outlets are more strongly associated with drinking problems, crime, and violence compared to outlets licensed for on-premise consumption only (Branas et al., 2011; Furr-Holden et al., 2016; Schonlau et al., 2008). Restaurants, hotels/motels, entertainment venues, and non-profit private clubs were not included in this study as these establishments only allow on-premise alcohol consumption.

To assess pedestrian safety infrastructure around alcohol outlets, raters took part in a 30-minute training which reviewed the study's purpose, protocol, and definitions of all terms, complete with pictures of common roadway features. Raters were given a field guide with the same information. Raters evaluated the roadway features around every off-premise alcohol outlet location (n=685); a quarter of these locations (n=172) were double coded to assess reliability of the tool. Double-coded locations were selected from various neighborhoods across Baltimore City, representing a socioeconomically and racially diverse sample of the City.

Raters went out in groups of three—one driver and two coders—in order to complete one full assessment of the liquor store and the surrounding pedestrian safety environment. For double-coded assessments, each coder rated the street segment separately to create two independent IPSI assessments. Raters were instructed to walk the block as many times as necessary to thoroughly collect all measures; if a neighborhood was considered unsafe, raters drove the block and intersection several times until all measures were complete. For double-coded locations, raters were instructed not to discuss or share their assessments. Data were coded on paper forms that were the size of a half sheet of paper. Each IPSI assessment took approximately 20 minutes to complete. Data sheets included the venue identification number on each page to ensure each section of the assessment could be linked to the venue. After each coding session, raters debriefed with project staff to pose questions and return data sheets for data entry. Data sheets were also reviewed by project staff to assess comprehensiveness and accuracy of data collection.

Google Street View Data Collection

The 172 double-coded alcohol outlet locations were reassessed using GSV by a new set of raters who had not participated in the in-person assessment. Two GSV raters coded the same street segments assessed by the in-person raters to create two new, independent IPSI assessments for each of the 172 locations. GSV raters took part in the same 30-minute training as the in-person raters and were instructed not to discuss or share their assessments. The IPSI instrument was also unchanged, except raters were asked to note the month and year the image was captured for each block and intersection to assess coding discrepancies related to temporal changes in roadway features and GSV image dates (Curtis et al., 2013). Raters were instructed to type the alcohol outlet's address into the

GSV address bar and scan the area as many times as necessary and from as many angles as necessary to thoroughly assess the block (Figure 4.2). Raters were instructed to judge the infrastructure by the most recent image, even if it did not give the most complete view of the street. Each assessment took approximately seven minutes to complete. As with the in-person observation, data collection was paper based, and data sheets were reviewed by project staff to assess comprehensiveness and accuracy of data collection. Data collection took place from February to March 2016.

This study was reviewed by the Johns Hopkins University IRB and deemed non-human subjects research.

Analysis

Data sheets collected from the four independent observations (two in-person and two GSV) were entered into SPSS 20 for reliability analysis. Inter-rater reliability was assessed for each observation pair and across all four observations to first assess the reliability of the IPSI itself and the reliability of GSV results. For categorical measures, Cohen's Kappa was calculated for each paired response and two-way mixed single measure consistency intra-class correlation coefficient (ICC) was calculated for four-way reliability (Fleiss & Cohen, 1973; Hallgren, 2012; Norman & Streiner, 2008). For continuous responses, two-way random average measure consistency ICC coefficients were calculated for each paired response and for four-way reliability (Hallgren, 2012). Certain features did not show any variability across locations and are labeled "Constant," indicating their consistent presence or absence from the streetscape. Features with variability across streetscapes but perfect agreement across paired or four-way observers are labeled as "1.00," indicating perfect agreement among observers across every observed location.

Exploratory factor analysis (EFA) with principal component extraction and verimax rotation was employed to develop intersection and roadway features scales to assess internal consistency. The purpose of EFA was to identify clusters of homogenous variables that could be used to assess the presence of safety infrastructure without having to collect the entire data form. Eigenvalues of greater than 1 were used as criterion for factor extraction; items with loadings of less than 0.15 and double-loaded items were dropped. Items that were significantly correlated (polychoric correlation $p<0.05$) with two or more variables were excluded as these items tended to assess similar characteristics. A Cronbach's alpha of 0.6 or greater was accepted as a measure of internal consistency for each scale (Cortina, 1993). Selected items were deleted to improve the Cronbach's alpha of the scales.

RESULTS

Inter-rater reliability estimates for categorical variables are presented in Table 4.22; reliability estimates for continuous variables are presented in Table 4.3. Overall, roadway features on the primary roadway (labeled Roadway 1 in Tables 4.2 & 4.3) showed strong reliability for paired observations and four-way observation. Bus stops (ICC=0.813, 95%CI=(0.763, 0.855)) and one-way streets (ICC=0.936, 95%CI=(0.918, 0.950)) showed the highest reliability across all four raters, while presence of street lights, alley streets, driveways and speedhumps showed moderate agreement with four-way ICCs between 0.60 and 0.65. Sidewalk maintenance reliability was consistently the lowest measure across all paired and four-way measures with an overall ICC of 0.43 (95%CI=(0.27, 0.55)). Presence of posted speed limits showed moderate agreement across all groups (ICC=0.61, 95%CI=(0.50, 0.70)), while agreement on the speed limit itself was strong (ICC=0.93, 95%CI=(0.83, 0.98)). Pedestrian overpasses and highway exit-ramps were not present; consequently, reliability of these measures could not be assessed. Reliability of second roadway measures (for corner stores only, n=64) were similar to those of the first roadway, with a few exceptions. Four-way reliability for alley streets (ICC=0.35, 95%CI=(0.02, 0.59) and driveways (ICC=0.29, 95%CI=(0.15,0.44)) showed the lowest agreement, while reliability for observed sidewalk maintenance (ICC=0.61, 95%CI=(0.41, 0.75)) was higher.

Intersection features were particularly strong with most features showing ICCs above 0.80 for all paired comparisons and four-way comparisons; these included crosswalks, traffic lights, stop signs, yield signs, pedestrian crossing signals, and set-back street stop lines. There was moderate reliability of pedestrian crossing signs (ICC=0.594, 95%CI=(0.485, 0.685)), and no crosswalks with embedded reflectors were observed.

The majority of midblock safety features were not observed, with the exception of traffic circles and pedestrian crossing signs. Traffic circles showed perfect agreement across groups. The number of midblock pedestrian crossing signs showed high agreement across all paired and four-way comparisons with an ICC for each grouping of approximately 0.80.

During EFA, intersection variables were highly correlated. Street stop line was highly positively significantly correlated with crosswalks at signalized intersections ($r=0.899$, $p<0.001$), traffic lights ($r=0.75$, $p<0.001$), and pedestrian crossing signals ($r=0.66$, $p<0.001$). The intersection measures yielded one distinct scale with high internal consistency: crosswalks, traffic lights, signalized pedestrian crossing, set-back stop lines (alpha=0.86) (Table 4.4). There was less correlation among roadway features, which also produced one distinct scale: number of street lanes, presence of driveways, type of parking, presence of bus stops (alpha=0.60). Because so few of the midblock items were present in the sample, we could not perform EFA on these items.

We also recorded the date of GSV images to account for disagreement related to temporal variability of images across locations and temporal discontinuity of images taken at main roadways versus intersections at the same location (Curtis et al., 2013). There were large temporal inconsistencies across locations and between intersections and main roadways. Thirty-four percent (n=59) of intersection images were recorded August to October 2015 or roughly within one month of in-person observation, while 29% (n=50) of images were taken during the same months for main roadways. In addition, 48.8% (n=84) of intersection images were recorded from September to October 2014, and almost 20% (n=29) of intersection images were recorded prior to 2014—greater than one year prior to in-person data collection. Half (n=86) of main roadway images were recorded from September to October 2014, while 21% (n=36) of images were taken before 2014.

DISCUSSION

This study evaluates an evidence-based tool for assessing pedestrian safety infrastructure, either through in-person observation or GSV. The majority of items had good or excellent levels of inter-rater reliability, with intersection features showing the highest agreement across raters. The strong interitem reliability of the intersection scale is also a strength of the IPSI, especially considering the high number of pedestrian injuries which occur at intersections (Roudsari et al., 2006). We developed and evaluated the reliability of our instrument before engaging in GSV testing; previous studies of environmental observation tools for traffic safety have evaluated their tool's reliability for GSV use without first testing the reliability of the tool itself (Bader et al., 2015; Rundle et al., 2011).

As with previous evaluations of observational tools to assess the built environment (Bader et al., 2015; Mooney et al., 2016; Rundle et al., 2011), we found that the use of GSV provides a reliable alternative to in-person street audits for safety infrastructure. GSV is a low-cost, easy-to-implement alternative to in-person audits that produces relatively quick turn around on data collection (Mooney et al., 2016; Rundle et al., 2011). Consequently, GSV allows for a wider area to be surveyed compared to in-person audits, without the need for additional resources or time (Clarke et al., 2010).

The IPSI provides a reliable environmental audit tool designed to assess a variety of pedestrian safety research questions quickly and efficiently. For example, the IPSI can be used to assess pedestrian safety infrastructure around specific neighborhood features such as playgrounds, schools, corner stores, or older adult communities. It can also be used to assess the prevalence of infrastructure at specific locations, such as the prevalence of stop signs in areas of high versus low alcohol outlet density. In addition, the two scales can be used to assess overall roadway and intersection infrastructure. Future research will evaluate the predictive validity of the IPSI, in particular the validity of the two scales for evaluating pedestrian injury risk at intersections and main roadways.

Limitations

This study only assessed street infrastructure in one metropolitan area. Certain features of Baltimore's streetscapes may limit the generalizability of findings to other urban settings. For example, lanes change from driving to parking for certain times of day, and signage may not be readily apparent denoting the change. The temporal variation in on-street parking may limit the reliability of findings depending on when in-person observers visited the locations and when GSV images were taken. Alley streets are also unique to Baltimore, and there may be confusion across raters as to what is an alley versus a residential street (Hayward, 2008). As noted by Mooney and colleagues (2014), rater familiarity with a neighborhood is an inherent limitation to the environmental observation method as raters familiar with a neighborhood may interpret characteristics differently than raters to whom the neighborhood is unfamiliar. Investigation of the IPSI's reliability in a variety of urban and suburban settings will enhance generalizability.

Furthermore, every IPSI item is weighted as equally important in influencing pedestrian safety. It is possible that certain infrastructure features are more impactful in protecting pedestrians than others. Future research should examine the relative importance of pedestrian safety infrastructure and weight IPSI items accordingly. The absence of traffic and pedestrian volume measures could also be a limitation when using the IPSI to evaluate pedestrian safety. As the aim of the IPSI is to capture the relatively static nature of roadway infrastructure, the absence of these more temporal measures is not an inherent drawback of the tool.

The limitations of GSV as an observational tool are also worth discussing. Because of the lack of fine detail available in images, subjective measures such as sidewalk maintenance may not be reliable (Griew et al., 2013; Vanwolleghem et al., 2014). Obstruction also could be problematic as signage, particularly smaller signs such as speed limits or pedestrian crossing signs, as well as driveways and alley streets, may be blocked by trees, trucks or other vehicles when the image was captured (Bader et al., 2015). GSV images are also not updated consistently (Curtis et al., 2013). In our study, a third of intersection images were taken within one month of in-person observation and less than 30% were taken within one month for main roadways. This temporal delay in images could reduce the reliability of GSV measures compared to in-person observation.

Conclusion

As the urban landscape and associated pedestrian behavior transform, continued investigation of street-level risk factors and evolving public health prevention strategies are necessary for ensuring pedestrian safety. The growing popularity of mixed-use land developments, public transportation, and alternative “green” methods of transportation will continue to increase pedestrian activity, while distractions from multimedia devices and cell phones will create new challenges for pedestrian safety (Miranda-Moreno et al., 2011; Schwebel et al., 2012). The IPSI provides a valid, economically-efficient tool for assessing urban safety infrastructure that can be employed for a variety of research and urban planning needs. Reliable and valid measurement of pedestrian safety infrastructure is necessary to effectively prevent future pedestrian injuries.

Table 4.1. Pedestrian Safety Infrastructure Inventory features and definitions

Domain	Definition
Roadway Features	
One-way or two-way street	
Number of street lanes	Total number of lanes, regardless of direction
Posted Speed Limit	Yes or No
If speed limit can be read, please enter it.	Write down the posted speed limit if you see it.
Street lights or lampposts	Yes or No
On-street parking	No on-street parking; Parallel parking only; Diagonal parking only; Both parallel and diagonal parking
Presence of alley streets	Yes or No; The alley could have a name or no name
Presence of driveways	Yes or No
Sidewalks	No sidewalks; Sidewalk on one side of the street only; Sidewalk on both sides of the street
Sidewalk maintenance and walkability	Good=Sidewalk is in pristine or near pristine condition, very easy to go across; Fair=Sidewalk has some unevenness and obstacles, but it can still be navigated; Poor=Sidewalk is extremely difficult or nearly impossible to go across
Traffic island or median	Yes or No
Speed bumps or humps	Yes or No
Pedestrian overpass, underpass, or bridge	Yes or No
Fence or other barrier to prevent street crossing	Yes or No
Bus stops	Yes or No
Highway on-ramp or exit-ramp	Yes or No
Midblock Features	
Number of marked mid-block crosswalks	Crosswalks are marked with white painted lines, colored painted lines or zebra striping
Number of crosswalks with reflectors or flashing lights embedded in pavement to mark crosswalk	
Number of pedestrian crossing signs	
Number of pedestrian crossing signals	
Intersection Features	
Traffic circle or roundabout	Yes or No
Number of intersecting streets	Example: If there are 4 corners at an intersection, then 2 streets are intersecting
Number of marked crosswalks at an intersection at the site of a pedestrian walk signal, stop light or stop sign	Crosswalks are marked with white painted lines, colored painted lines or zebra striping.

Domain	Definition
Intersection Features	
Number of marked crosswalks at intersection NOT associated with pedestrian walk signal, stop light or stop sign	Crosswalks are marked with white painted lines, colored painted lines or zebra striping
Number of crosswalks with reflectors or flashing lights embedded in pavement to mark crosswalk	
Number of streets with traffic lights	Traffic light=traffic signal or stop light
Number of stop signs	
Number of yield signs	
Number of pedestrian crossing signals	
Number of pedestrian crossing signs	
Number of streets with stop line set back from crosswalk	

Figure 4.1. Diagram of data collection protocol at alcohol outlets located at a corner

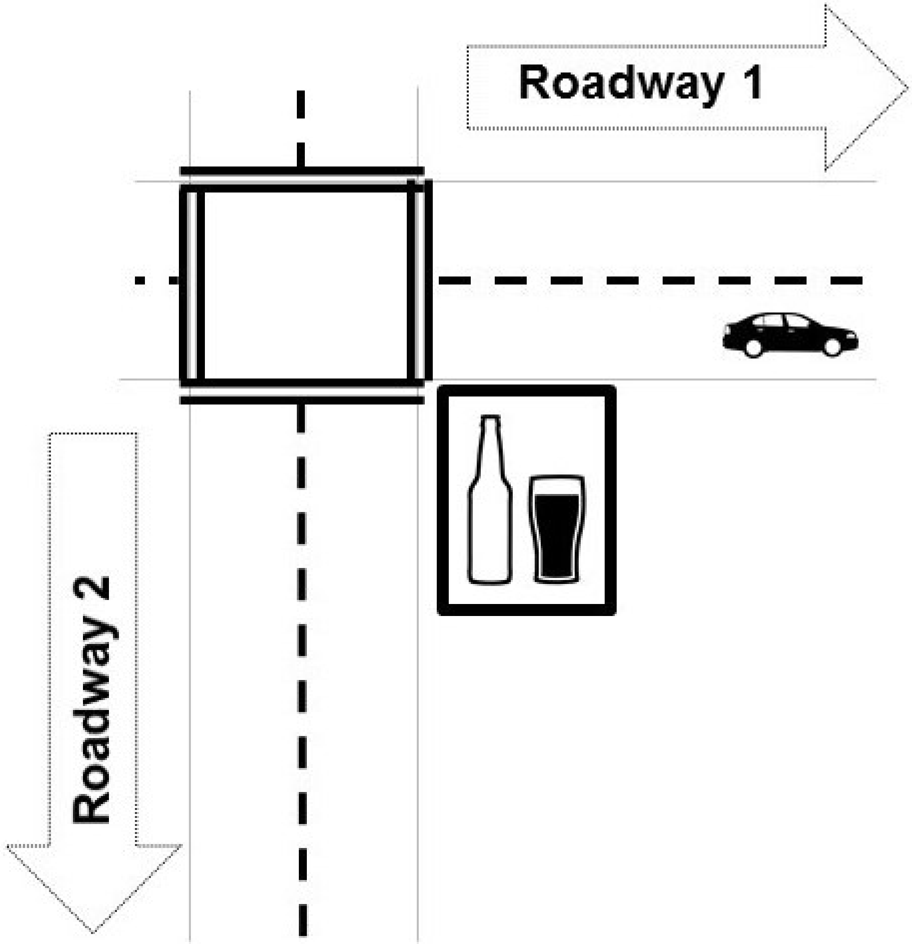

Figure 4.2. Example of data collection using Google Street View

Example IPSI measures:
A: Address of alcohol outlet; Month and Year image was captured
B: Presence of streetlights/lampposts
C: One-way street and Stop sign
D: Sidewalks on both sides of street in good condition

Table 4.2. Cohen's Kappa and Intra-Class Correlation (ICC) for Categorical Variables

Item	In-Person Observation			Google Street View Observation			Across All Observations		
	Kappa Coefficient	SE	P-value	Kappa Coefficient	SE	P-value	ICC	95% CI	P-Value
Roadway 1 (n=172)									
One-way or two-way street	0.856	0.044	<0.001	0.921	0.032	<0.001	0.936	0.918, 0.950	<0.001
Posted speed limit	0.214	0.079	0.005	0.572	0.073	<0.001	0.610	0.504, 0.697	<0.001
Street lights or lampposts	1.000	0.000	<0.001	0.797	0.198	<0.001	0.627	0.514, 0.703	<0.001
On-street parking (parallel or diagonal/back-in parking)	0.653	0.121	<0.001	0.695	0.086	<0.001	0.635	0.568, 0.699	<0.001
Presence of alley streets	0.501	0.075	<0.001	0.560	0.067	<0.001	0.614	0.510, 0.701	<0.001
Presence of driveways	0.443	0.155	<0.001	0.624	0.060	<0.001	0.582	0.470, 0.676	<0.001
Sidewalk on one or both sides of street?	Constant			1.000	0.000		0.667	0.577, 0.741	<0.001
Traffic island or median	0.900	0.044	<0.001	0.853	0.054	<0.001	0.937	0.920, 0.951	<0.001
Speed bumps or humps	Constant			0.496	0.306	<0.001	0.590	0.480, 0.682	<0.001
Pedestrian overpass, underpass, or bridge	Constant			Constant			Constant		
Fence or other barrier to prevent street crossing	Constant			Constant			Constant		
Bus stops	0.740	0.052	<0.001	0.595	0.067	<0.001	0.813	0.763, 0.855	<0.001
Highway on- or exit-ramp	Constant			Constant			Constant		
Roadway 2 (n=64)									
Corner Store?	0.951	0.024	<0.001	1.000					
One-way or two-way street	0.787	0.082	<0.001	0.805	0.076	<0.001	0.853	0.777, 0.907	<0.001
Posted speed limit	0.255	0.128	0.039	0.739	0.092	<0.001	0.666	0.494, 0.790	<0.001
Street lights or lampposts	Constant			0.703	0.162	<0.001	0.543	0.307, 0.712	<0.001
On-street parking (parallel or diagonal/back-in parking)	0.129	0.161	0.166	0.805	0.109	<0.001	0.837	0.753, 0.897	<0.001

Item	In-Person Observation			Google Street View Observation			Across All Observations		
	Kappa Coefficient	SE	P-value	Kappa Coefficient	SE	P-value	ICC	95% CI	P-Value
Presence of alley streets	0.050	0.127	0.690	0.449	0.111	<0.001	0.351	0.017, 0.591	0.021
Presence of driveways	0.213	0.202	0.045	0.557	0.099	<0.001	0.288	0.154, 0.441	<0.001
Sidewalk on one or both sides of street?	Constant			Constant			Constant		
Traffic island or median	0.734	0.178	<0.001	1.000	0.000	<0.001	0.590	0.379, 0.742	<0.001
Speed bumps or humps	Constant			1.000	0.000	<0.001	0.667	0.495, 0.790	<0.001
Pedestrian overpass, underpass, or bridge	Constant			Constant			Constant		
Fence or other barrier to prevent street crossing	Constant			Constant			Constant		
Bus stops	0.518	0.133	<0.001	0.817	0.125	<0.001	0.676	0.509, 0.796	<0.001
Highway on- or exit-ramp	Constant			Constant			Constant		
Intersection (n=172)									
Traffic circle or roundabout	1.000	0.000	<0.001	1.000	0.000	<0.001	1.000		

"Constant" indicates no variability across locations
"1.00" indicates perfect agreement among observers across every observed location

Table 4.3. Intra-Class Correlation (ICC) for continuous variables

Item	In-Person Observation			Google Street View Observation			Across All Observations		
	ICC	95% CI	P-value	ICC	95% CI	P-value	ICC	95% CI	P-value
Roadway 1 (n=172)									
Number of street lanes	0.805	0.736, 0.855	<0.001	0.916	0.886, 0.938	<0.001	0.899	0.872, 0.922	<0.001
Speed Limit	0.514	-0.146, 0.794	0.049	1.000			0.933	0.825, 0.981	<0.001
Sidewalk maintenance and walkability	0.347	0.118, 0.517	0.003	0.459	0.268, 0.600	<0.001	0.425	0.270, 0.554	<0.001
Midblock Features 1									
Number of marked mid-block crosswalks	Constant			Constant			Constant		
Number of crosswalks with reflectors or flashing lights	Constant			Constant			Constant		
Number of pedestrian crossing signs	0.718	0.620, 0.792	<0.001	0.710	0.608, 0.786	<0.001	0.570	0.455, 0.667	<0.001
Number of pedestrian crossing signals	Constant			Constant			Constant		
Roadway 2 (n=64)									
Number of street lanes	0.192	-0.331, 0.509	0.201	0.823	0.712, 0.891	<0.001	0.605	0.401, 0.751	<0.001
Speed limit	1.000			1.000			1.000		
Sidewalk maintenance and walkability	0.388	-0.008, 0.628	0.027	0.584	0.323, 0.744	<0.001	0.608	0.407, 0.754	<0.001
Midblock Features 2									
Number of marked mid-block crosswalks	Constant			Constant			Constant		
Number of crosswalks with reflectors or flashing lights	Constant			Constant			Constant		
Number of pedestrian crossing signs	0.802	0.675, 0.880	<0.001	0.741	0.578, 0.841	<0.001	0.786	0.676, 0.865	<0.001
Number of pedestrian crossing signals	Constant			Constant			Constant		
Intersection (n=172)									
Number of intersecting streets	0.658	0.538, 0.747	<0.001	0.850	0.797, 0.889	<0.001	0.827	0.780, 0.866	<0.001

Item	In-Person Observation			Google Street View Observation			Across All Observations		
	ICC	95% CI	P-value	ICC	95% CI	P-value	ICC	95% CI	P-value
Number of marked crosswalks at an intersection at the site of a walk signal, stop light or stop sign	0.892	0.854, 0.920	<0.001	0.948	0.930, 0.961	<0.001	0.929	0.910, 0.945	<0.001
Number of marked crosswalks at intersection NOT associated with walk signal, stop light or stop sign	0.923	0.896, 0.943	<0.001	0.874	0.830, 0.907	<0.001	0.918	0.896, 0.937	<0.001
Number of crosswalks with reflectors or flashing lights	Constant			Constant			Constant		
Number of streets with traffic lights	0.946	0.927, 0.960	<0.001	0.950	0.933, 0.963	<0.001	0.943	0.927, 0.956	<0.001
Number of stop signs	0.791	0.717, 0.845	<0.001	0.945	0.925, 0.959	<0.001	0.874	0.840, 0.902	<0.001
Number of yield signs	Constant			0.938	0.915, 0.954	<0.001	0.860	0.822, 0.891	<0.001
Number of pedestrian crossing signals	0.895	0.857, 0.922	<0.001	0.940	0.919, 0.956	<0.001	0.908	0.883, 0.928	<0.001
Number of pedestrian crossing signs	0.732	0.638, 0.801	<0.001	0.808	0.740, 0.858	<0.001	0.594	0.485, 0.685	<0.001
Number of streets with stop line set back from crosswalk	0.771	0.691, 0.831	<0.001	0.934	0.911, 0.951	<0.001	0.845	0.804, 0.880	<0.001

"Constant" indicates no variability across locations
"1.00" indicates perfect agreement among observers across every observed location

Table 4.4. Intersection and Roadway Features Scales

Domain	Items	Cronbach's Alpha*
Roadway	Number of street lanes	0.60
	Presence of driveways	
	On-street parking (parallel or diagonal/back-in parking)	
	Bus stops	
Intersection	Number of marked crosswalks at an intersection at the site of a walk signal, stop light or stop sign	0.86
	Number of streets with traffic lights	
	Number of pedestrian crossing signals	
	Number of streets with stop line set back from crosswalk	

*A Cronbach's alpha of 0.6 or greater was accepted as a measure of internal consistency for each scale (Cortina, 1993).

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CHAPTER 5. THE NEIGHBORHOOD ALCOHOL ENVIRONMENT & INJURY RISK: A SPATIAL ANALYSIS OF PEDESTRIAN INJURY IN BALTIMORE CITY

ABSTRACT

Excessive alcohol consumption is a leading contributor to pedestrian injury, yet consumption patterns alone do not account for increased pedestrian injury rates in communities where alcohol outlets are located. The purpose of this study was to investigate the impact of alcohol outlets on the neighborhood relative risk of pedestrian injury, as well as to investigate the contribution of neighborhood disorder to pedestrian injury risk. A spatial analysis was conducted on census block groups in Baltimore City. Data included pedestrian injury EMS records from January 1, 2014, to April 15, 2015 (n=858), off-premise alcohol outlet locations for 2014 (n=693), and neighborhood disorder indicators and demographics. Negative binomial regression models were used to determine the relationship between alcohol outlet count and pedestrian injuries at the census block group level, controlling for other neighborhood factors. Spatial correlation was assessed and regression inference adjusted accordingly. Each one-unit increase in the number of alcohol outlets was associated with a 19.3% (95% CI=(1.146, 1.245)) increase in the relative risk of neighborhood pedestrian injury, adjusting for traffic volume, population density, percent of vacant lots, and median household income. The attributable risk was 18.8% (95% CI=(16.1, 21.5)) or 155 extra injuries. Vacant lots was the only significant neighborhood disorder indicator in the final adjusted model (RR=1.023, 95%CI=(1.014, 1.032)). This study reinforces the importance of alcohol outlets in understanding neighborhood pedestrian injury risk, identifies new risk factors for pedestrian injury previously unexplored in the literature, and provides important public health evidence for alcohol control strategies (e.g., liquor store licensing, zoning, and enforcement).

Keywords: pedestrian injury, alcohol outlets, spatial analysis, neighborhood disorder

INTRODUCTION

Excessive alcohol consumption is a leading contributor to pedestrian injury and fatality in the United States. Alcohol consumption was involved in 48% of motor vehicle crashes that resulted in pedestrian fatalities in 2014; 34% of pedestrians had blood alcohol concentration (BAC) of 0.08 g/dL or higher, while only 14% of drivers involved in these crashes had BAC of 0.08 g/dL or higher (National Center for Statistics and Analysis, 2016). Alcohol consumption adversely affects the observational, cognitive, and physical skills of pedestrians, including detecting vehicles in motion and initiating actions (Oxley et al., 2006). As a result, pedestrians who consume alcohol are more likely to cross the street in an unsafe manner, such as against the light or midblock (Dultz et al., 2011). Intoxicated pedestrians also experience more severe injuries and suffer longer recovery times compared to sober pedestrians (Dultz et al., 2011; Plurad et al., 2006).

However, the effect of alcohol outlets on pedestrian injury extends beyond alcohol consumption by individuals as consumption patterns alone do not account for increased pedestrian injury rates in communities where alcohol outlets are located. One study found that the effect of increased alcohol outlet density on injury risk was independent of the effect of increased alcohol consumption (Campbell et al., 2009). Furthermore, the presence of alcohol outlets in a neighborhood does not consistently correspond with community demand for alcohol (Ahern et al., 2013; Gmel et al., 2016). Resource-deprived census tracts and predominantly Black census tracts have significantly more liquor stores per capita than more affluent communities and predominantly White communities, yet Blacks consume less alcohol compared to Whites (LaVeist & Wallace, 2000; Romley et al., 2007). A study conducted in California found that, although the most resource-deprived neighborhoods had the highest density of alcohol outlets, residents of the least deprived neighborhoods had the highest levels of heavy alcohol consumption, even after controlling for a range of individual characteristics (Pollack et al., 2005).

The discrepancy between alcohol supply and demand in a community may cause residents of resource-deprived neighborhoods to disproportionately suffer the negative health consequences of living near alcohol outlets. Neighborhoods with higher concentrations of alcohol outlets experience more interpersonal violence and crime (Franklin et al., 2010; Furr-Holden et al., 2016; Jennings et al., 2014; Lipton et al., 2013). Furthermore, alcohol outlets, particularly off-premises packaged goods stores, are often surrounded by signs of social and physical disorder, such as empty or broken bottles, loiterers, and publicly intoxicated patrons (Branas et al., 2009; Cunradi, 2010; Scribner et al., 2007). Physical disorder refers to the deterioration of the urban landscape, including graffiti, litter, vacant lots, and broken windows, while social disorder indicates behavior which may be considered threatening, such as verbal harassment on the street or public intoxication (Sampson & Raudenbush, 1999). Greater neighborhood presence of alcohol outlets in and of itself is a visible indication of increased disorder (Cunradi, 2010; Gorman et al., 2001). Residents of neighborhoods with a high concentration of alcohol outlets may be less likely to spend time outdoors and to network in a way that builds healthy social relationships as community members may be competing with social networks associated with disorder, crime, and other incivilities surrounding alcohol outlets (Theall et al., 2009).

While only a handful of studies have examined the impact of alcohol outlets on pedestrian injury risk, the majority of these studies focused on alcohol-involved crashes—crashes where the pedestrian, the driver, or both were intoxicated (DiMaggio et al., 2016;

Escobedo & Ortiz, 2002; LaScala et al., 2001; Treno et al., 2007). Few studies have examined the impact of alcohol outlets on pedestrian injury risk above and beyond that attributable to intoxication, and no studies have examined this relationship independent of intoxication. There is evidence that pedestrian injury hotspots overlap areas of greater alcohol outlet concentration. In a Vancouver study, two-thirds of pedestrian injury hotspots were located immediately proximal to an alcohol outlet, and almost one-third of all hot spots were located in areas of high alcohol outlet concentration (Schuurman et al., 2009). The occurrence of pedestrian injuries around alcohol outlets may be a result of the diverse physical and social characteristics of the community in which the injuries occur (Gruenewald, 2007; Toomey et al., 2012; Treno et al., 2007). Little research exists which conceptualizes the mechanisms by which alcohol outlets impact pedestrian injury risk.

The purpose of this study was to investigate the impact of alcohol outlets on the neighborhood relative risk of pedestrian injury. We hypothesized that increased numbers of alcohol outlets in a neighborhood would correspond with increased relative risk for pedestrian injuries. We also aimed to investigate indicators of neighborhood physical and social disorder as possible contributors to neighborhood pedestrian injury risk. We hypothesized that neighborhoods with greater physical disorder and lower positive social activity would experience greater relative risk for pedestrian injury.

METHODS

This research was approved by the Institutional Review Board at the Johns Hopkins Bloomberg School of Public Health.

Data Sources

Pedestrian injury data were gathered through emergency medical services (EMS) records collected from January 1, 2014, to April 15, 2015 (n=848). The Baltimore City Fire Department (BCFD) operates the City's EMS system, which deploys paramedics in response to all calls within the city limits (Knowlton et al., 2013). As Baltimore City's residents are served by a single EMS system, these data are representative of all EMS calls for pedestrian injuries (Cusimano et al., 2010). Furthermore, paramedics on the scene confirmed that the injury was caused by a motor vehicle crash. When an emergency call was received, Dispatch administered a brief set of questions to the caller to determine the severity of the patient condition, then asked the patient's location; Dispatch then relayed the message to paramedics. Once on the scene, paramedics evaluated the patient and filled out the EMS patient report that included the code for pedestrian injury. Paramedics recorded patient-level and other incident-related data on wireless tablet computers using proprietary software that was developed in compliance with the Electronic Maryland Ambulance Information System (Knowlton et al., 2013). Patient information included demographics; transport status and patient disposition; patient priority; suspected drug or alcohol use; and paramedic-reported impression of the primary health problem. Ambulances are routinely sent to precise locations of injured persons, allowing for the geographic mapping of injury events to better define high-risk locations (Cusimano et al., 2010; Ryb et al., 2007). EMS data also provide a measure of when an injury occurred in addition to geographic location, allowing for examination of temporal variation in injury risk (Cusimano et al., 2010).

Locations of alcohol outlets in 2014 were obtained through the Board of Liquor License Commissioners for Baltimore City. There are 12 liquor license types administered by the Board. This study focused on the four licensure classes concerned with sale of package goods for off-premise consumption—liquor packaged goods stores, bars/taverns, and wine and beer only stores (n=693) (Campbell et al., 2009; Milam et al., 2014). On- and off-premise outlets differentially impact injury risk. Off-premise outlets are more strongly associated with drinking problems, crime, and violence compared to outlets licensed for on-premise consumption only (Branas et al., 2011; Furr-Holden et al., 2016; Schonlau et al., 2008). Restaurants, hotels/motels, entertainment venues, and non-profit private clubs were not included in this study as these establishments only allow on-premise alcohol consumption.

Neighborhood data: Assessments of the neighborhood environment were obtained using The Neighborhood Inventory for Environmental Typology (NIfETy) instrument (Furr-Holden et al., 2008). NIfETy is a standardized inventory designed to assess characteristics of the neighborhood environment related to violence, alcohol, and other drug (VAOD) exposures (Milam et al., 2014). The NIfETy Instrument includes 75 items operationalized into seven domains: physical layout, types of dwellings, adult activity, youth activity, physical order and disorder, social order and disorder, and VAOD indicators (Furr-Holden et al., 2008). For this analysis, we used data collected from July to November 2012, the last year city-wide data collection took place; data collection took place on a random sample of 802 blocks located throughout the city. Full details of the data collection methodology and block selection can be found in Furr-Holden et al. (2008). The NIfETy has strong psychometric properties; the ICC for the total scale is 0.84, 0.71 for the VAOD scale, and 0.67 to 0.79 across raters (Furr-Holden et al., 2010). Validity metrics are also strong (Furr-Holden et al., 2010).

Vacant lots: Addresses for all vacant lots in Baltimore City in 2015 were compiled by the Baltimore City Housing Authority (City of Baltimore, n.d.). Digital parcel maps of all lots in Baltimore City were available through the Maryland State Department of Planning (Maryland Department of Planning, n.d.). Vacant lots are an important indicator of neighborhood disorder and have significant effects on community health and safety (Branas et al., 2012; Kondo et al., 2016). A qualitative study of vacant lots' impact on community well-being found that vacant lots overshadowed positive aspects of the community, eroding community cohesion, attracting crime, and increasing residents' fear and anxiety (Garvin et al., 2013). Residents also felt significant stigma associated with living in a disordered neighborhood and felt unfairly judged by outsiders, further contributing to self-reported sadness and depression (Garvin et al., 2013).

Pedestrian safety infrastructure: No comprehensive database cataloging Baltimore City's traffic safety infrastructure exists, in part because of the logistical and methodological challenges of maintaining such a database (City of Baltimore Department of Transportation, 2015). The Inventory for Pedestrian Safety Infrastructure (IPSI) is a standardized instrument designed to assess the presence of street-level infrastructure for preventing pedestrian injury. The IPSI is evidence-based and includes three domains: roadway features, midblock features, and intersection features. The majority of items had good or excellent levels of inter-rater reliability (ICC$\geq$0.8), with intersection features showing the highest agreement across raters. The IPSI also has been validated for use with Google Street View (GSV) in place of in-person data collection; GSV images are time-stamped with the month and year an image was processed, and many locations allow the user to travel back in time to every previous image taken at a location. Data collection took place on the same sample of 802 blocks selected by the NIfETy sampling methodology. IPSI data were collected from December to February 2017, but IPSI measures were collected for images taken on or before April 2015 to coincide with the dates of EMS data collection.

Traffic volume: Traffic volume is an important predictor of pedestrian injury risk (Lassarre et al., 2007; Morency et al., 2012). Average Daily Traffic Volume for 2013—the most recent year of data availability—was collected by the Maryland State Highway Administration's Traffic Monitoring System (Maryland State Highway Administration, n.d.). Traffic counts are recorded at a specific point on the roadway referred to as a "count station" but extrapolated to represent the entire section of roadway by a linear referencing system integration process. These data are then mapped for use as both a point file and a street segment file. There are 752 count stations in Baltimore City; 168 (22.3%) count stations located on highways were excluded to create a measure of traffic volume for residential roadways (n=584).

Schools: A list of all public, private, charter, and special education schools for kindergarten through grade 12 in 2015 was compiled through the Maryland State Department of Education and the Baltimore City Public Schools (Baltimore City Public Schools, n.d.; Maryland State Board of Education, n.d.) (n=239). Proximity to schools has been associated with increased pedestrian injury incidence, particularly for school-aged children (Abdel-Aty et al., 2007; Clifton & Kreamer-Fults, 2007; LaScala et al., 2004).

Demographic variables for each census block group in Baltimore City (n=653), including population totals and median household income, were taken from the 2010 Census (U.S. Census Bureau, 2010). Increased population density and median household income have been associated with reduced pedestrian injury risk in previous research (Clifton et al., 2009; Ewing & Dumbaugh, 2009; Mohamed et al., 2013; Morency et al., 2012).

Measures

Physical Disorder and Social Activity scales: Eighteen binary items from the NIfETy were used to classify the neighborhood physical and social environment. These items were selected because they have been used in previous investigations (Cohen et al., 2003; Furr-Holden et al., 2015; Perkins & Taylor, 1996; Sampson, 1997). Twelve items were used to classify physical disorder in the neighborhood environment: broken windows; abandoned buildings; vacant houses; vacant lots; unmaintained properties; broken bottles; graffiti; evidence of vandalism; presence of intoxicated people, signs of using alcohol/drugs or signs of drug selling; syringes or vials; baggies, blunt guts/wrappers or pot roaches; alcohol bottles. Six items were used to classify social activity in the neighborhood environment: youth playing, youth sitting in a group, youth in transit, positive adult interactions, adults sitting on steps, adults watching youth. Items were summed to create two scales. Physical disorder score ranged from 0 to 12 with higher scores indicating higher levels of neighborhood physical disorder. Social activity score ranged from 0 to 6, with higher scores indicating higher levels of positive social activity. The Cronbach's alpha was 0.79 for the physical disorder scale and 0.66 for the social activity scale.

Intersection and Roadway Safety Infrastructure scales: Two four-item scales were developed from the IPSI to measure safety infrastructure at intersections and roadways. Intersection items measure the presence and number of marked crosswalks, streets with traffic lights, signalized pedestrian crossing, and streets with stop lines set back from the crosswalk. Roadway items include the number of street lanes, presence of driveways, type of parking, and presence of bus stops. Items were summed to create two infrastructure scales. Intersection scores ranged from 0 to 21 with higher scores indicating more infrastructure at intersections. Roadway scores ranged from 0 to 8 with higher scores indicating more infrastructure on roadways. The Cronbach's alpha was 0.86 for the intersection scale and 0.60 for the roadway scale.

Demographic measures: To calculate percent of vacant lots per block group, we aggregated the count of vacant lots and the count of all lots to each block group. We then divided the number of vacant lots by the total number of lots to calculate the percent of vacant lots in each block group. Population density was calculated by taking the total population of each block group and dividing by the area of the block group in square miles.

Data Analysis

Spatial Analysis. Locations of pedestrian injuries and alcohol outlets were geocoded and mapped using ArcGIS 10.4. To assess the initial hypothesis of a relationship between locations of pedestrian injuries and alcohol outlets, we mapped kernel intensity estimates to assess geographic variability among alcohol outlets and pedestrian injuries and calculated the Cross K function to assess clustering of pedestrian injuries around the fixed locations of alcohol outlets using R 3.3 (Waller & Gotway, 2004).

Count of pedestrian injuries and count of alcohol outlets were aggregated to the block group level to assess neighborhood effects. We performed Poisson regression in R 3.3, analyzing the counts of pedestrian injuries per block group, while adding each control variable in a stepwise fashion. As each control variable was added, we calculated over-dispersion statistics and Residual Moran's *I* to assess residual spatial variation not accounted for by the model's covariates (Waller & Gotway, 2004). We also calculated Akaike's Information Criterion (AIC) for each model to select the best fitting and most parsimonious model. Because the best-fitting Poisson model was over-dispersed with significant unexplained spatial variation, we repeated model selection with the negative binomial distribution using the same stepwise system of covariate selection. Negative binomial regression derives as an alternative to Poisson regression that accommodates over-dispersion. We again calculated AIC and Residual Moran's *I* to assess residual spatial variation. We also tested spatial lag effects using the same stepwise system of covariate selection. The final model presented here represents the best fitting, most parsimonious model with the least residual spatial variation according to the above criteria.

To calculate the neighborhood pedestrian injury risk attributable to the presence of alcohol outlets, we simulated a case-control study by comparing the total population count per block group (controls) to the number of injured pedestrians in a block group (cases). Using our final negative binomial model, we calculated the baseline injury risk assuming no alcohol outlets in Baltimore City. We then included alcohol outlets and compared the baseline pedestrian injury risk to the alcohol outlet-included injury risk. To facilitate this analysis, we removed the 13 block groups zoned nonresidential which had no population.

Missing Data. We aggregated the physical disorder, social activity, roadway and intersection infrastructure scales to the block group level. Because of the small size of block groups and the financial and temporal limitations of street sampling, 123 (18.8%) block groups lacked measures. To estimate the values for the missing block groups, we performed ordinary kriging to estimate a city-wide map of values for each of the four scales (Waller & Gotway, 2004). Using a planometric map of all Baltimore City streets, we assigned a kriged value for each scale to each street centroid. We then aggregated the centroid values to the block group level to calculate the average estimated score for each scale for each block group.

We aggregated average daily traffic flow to each block group to create an average measure of traffic volume through each block group. Six block groups (0.9%) had no recorded traffic observations. For these block groups, we assigned the value from the nearest count station to the block group. The smallest distance from a block group to a count station was 0.17ft and the farthest was 148.2ft. We surmise that these block groups were not assigned values by ArcGIS because of a geocoding error and not because they lacked traffic flow.

Sensitivity Analysis. We performed sensitivity analyses to assess the potential impact of biases associated with clustering. In particular, the downtown neighborhood block group contained 40 injured pedestrians and 32 alcohol outlets; in comparison, the next highest block group contained 13 injuries and 10 alcohol outlets. We included a measure to test the effect of distance from the downtown block group to each block group to see if this outlier block group significantly altered the relationship between alcohol outlets and pedestrian injury risk. Distance from downtown was calculated as the distance from the geographic centroid of the downtown block group to the centroid of each block group in miles. We next excluded the downtown block group entirely and reran our analyses to check that the injury-outlet relationship was not driven by the excessive number of outlets and injuries in this block group. We also excluded 13 block groups with missing demographic data—block groups that were industrial areas not zoned residential—and reran our analyses.

RESULTS

Table 5.1 shows the distribution of selected characteristics across block groups. There was an average of 1.3 (sd=2.36) pedestrian injuries per block group. The count of pedestrian injuries across block groups ranged from 0 to 40, with 46% of block groups (n=301) reporting no pedestrian injuries. The highest pedestrian injury count was reported in the downtown neighborhood with 40 injuries, followed by the adjoining block group with 13 injuries (Figure 5.1). The downtown block group also reported the highest count of alcohol outlets with 32 outlets, followed by two block groups in the southeastern section of the city with 12 outlets. Over half (n=365) of block groups did not contain an alcohol outlet; on average, there were 1.06 (sd=2.13) alcohol outlets per block group.

In the unadjusted negative binomial regression models, there was a statistically significant relationship between count of alcohol outlets and pedestrian injuries (Table 5.2). For each unit increase in alcohol outlets, there was a 21.1% increase in pedestrian injury risk (95%CI=(1.157, 1.273), $p<0.001$). School count, physical disorder score, social activity score, and roadway infrastructure score were not significant predictors of neighborhood pedestrian injury risk in univariate analysis ($p>0.05$). Percent of vacant lots was significantly positively correlated with physical disorder score ($r=0.666$, $p<0.0001$) and social activity score ($r=0.510$, $p<0.0001$), and school count was significantly negatively correlated with population density ($r=-0.166$, $p<0.0001$). As physical disorder score, social activity score, and school count were not significant in univariate analysis, these variables were excluded from the final model along with roadway infrastructure.

The final model—count of alcohol outlets, percent of vacant lots, median household income, population density, and traffic flow—was the most parsimonious and best-fitting model (AIC=1915) and exhibited no significant residual spatial variation (RMI=-0.002, $p=0.509$) (Table 5.2). Alcohol outlet count remained associated with pedestrian injury risk after controlling for selected neighborhood measures. Each unit increase in the number of alcohol outlets in a neighborhood was associated with a 19.3% increase in neighborhood pedestrian injury risk in the adjusted model (95%CI=(1.146, 1.245), $p<0.001$). The pedestrian injury risk attributable to alcohol outlets was 18.8% (95% CI=(16.1, 21.5)) or 155 extra injuries over baseline.

Vacant lots and median household income were also strong predictors of neighborhood injury risk. Each increasing percent of vacant lots in a block group was associated with a 2.3% (95%CI=(1.014, 1.032), $p<0.001$) increase in pedestrian injury risk. Median household income was protective of neighborhood pedestrian injury risk, with every $1,000 increase in median income associated with a 0.9% (RR=0.991, 95%CI=(0.988, 0.995), $p<0.001$) decrease in neighborhood pedestrian injury risk.

The spatial lag of traffic flow was found to be a better-fitting predictor of neighborhood injury risk than average neighborhood traffic flow. The spatial lag accounts for traffic volume in the surrounding block groups, creating a weighted average of traffic volume over the local area. This smooths neighborhood traffic volume and allows for a more effective estimation of traffic flow in each block group (Bivand et al., 2013). With every increase in 1,000 vehicles, neighborhood pedestrian injury risk increased by 9.1% (95%CI=(1.059, 1.126), $p<0.001$). Population density was marginally statistically significant; every increase in 1,000 people per square mile was associated with a 1.1% decrease in neighborhood pedestrian injury risk (RR=0.989, 95%CI=(0.980, 0.998), $p=0.054$).

Sensitivity Analysis. There was significant correlation between alcohol outlet count and distance from the downtown outlier block group ($r=-0.295$, $p<0.0001$) and alcohol outlet count and intersection score ($r=0.21$, $p<0.0001$). In multivariate analysis, we substituted distance from downtown and intersection score for alcohol outlet count to assess if injury risk was attributable to alcohol outlets or if count of alcohol outlets was a proxy measure for a different, highly-correlated variable. We found that the models replacing alcohol outlets with distance from downtown or intersection score both had significant unexplained spatial variation (RMIs=0.9 and 0.116 respectively, $p<0.0001$); both models also had worse AIC (1974 and 1987, respectively).

We reran our adjusted negative binomial model, excluding the outlier downtown block group and the nonresidential block groups, and did not find a significant change in the relationship between alcohol outlets and pedestrian injury risk. The removal of the downtown block group did not diminish the strength of the association between count of alcohol outlets and neighborhood pedestrian injury risk (RR=1.225, 95%CI=(1.172, 1.282), $p<0.001$); model fit also remained strong (AIC=1901). However, the Residual Moran's *I* for the model became significant (RMI=0.065, $p=0.0012$), indicating potential spatial variation unexplained by the covariates. Excluding the 13 nonresidential block groups did not significantly alter the magnitude of the relationship between alcohol outlets and pedestrian injury risk (RR=1.189, 95%CI=(1.172, 1.282), p<0.001). Model fit remained strong (AIC=1867), and the Residual Moran's *I* was not significant (RMI=0.002, p=0.431). Finally, we excluded both the downtown block group and the 13 nonresidential block groups and found no significant difference in the alcohol outlet-injury relationship (RR=1.220, 95%CI=(1.172, 1.282), p<0.001). Model fit remained strong (AIC=1854), but the Residual Moran's *I* was significant (RMI=0.075, p=0.0003).

DISCUSSION

The objective of this study was to determine the relationship between alcohol outlets and neighborhood pedestrian injury risk. Our findings suggest that there is a strong relationship between neighborhood presence of alcohol outlets and pedestrian injury risk in Baltimore City after controlling for selected neighborhood factors. Each increase in the number of alcohol outlets was associated with a 19.3% increase in the neighborhood relative risk of pedestrian injuries in the adjusted model. These findings are consistent with previous studies of the impact of alcohol outlets and alcohol outlet density on pedestrian injury risk conducted in several metropolitan areas of varying size across the United States (DiMaggio et al., 2016; Escobedo & Ortiz, 2002; LaScala et al., 2001; Treno et al., 2007). For example, a New York City study found that the presence of at least one alcohol outlet in a census tract increased the relative risk of alcohol-involved pedestrian or bicycle injury by 47% (DiMaggio et al., 2016). Another study of four California communities with populations over 150,000 found that alcohol-involved pedestrian crashes occurred more frequently in areas with greater bar density (LaScala et al., 2001).

We also aimed to investigate the contribution of neighborhood physical and social disorder to the relationship between alcohol outlets and pedestrian injuries. Our measures of neighborhood physical and social disorder were not significant predictors of pedestrian injury, but they were highly correlated with percent of vacant lots in a neighborhood. Percent of vacant lots was a strong predictor of neighborhood pedestrian injury risk with each increasing percent of vacant lots in a neighborhood associated with a 2.3% increase in risk. Vacant lots have not been widely studied as predictors of pedestrian injury; one Los Angeles study found that pedestrian injuries were lower in areas with vacant land, but this study equated vacant land with low-density zoning designations such as industrial zoning and open space (Loukaitou-Sideris et al., 2007). Vacant lot remediation has been shown to significantly decrease violent crime (Branas et al., 2016; Kondo et al., 2016); addressing vacant lots may also reduce neighborhood pedestrian injury risk.

Median household income was protective of pedestrian injury risk, consistent with previous research that demonstrated an inverse relationship between median household income and average number of injured pedestrians in a census tract (Morency et al., 2012). The ability of a community to respond to road safety issues is closely correlated with socio-economic privilege (Collins & Kearns, 2005). A qualitative study conducted in Oakland found that higher income neighborhoods were more successful and quicker at bringing about change compared to lower income neighborhoods; despite the organization and motivation of residents in the lower income neighborhood, it took them significantly longer to achieve their goals in increasing road safety (Altschuler et al., 2004).

Population density was marginally significantly associated with pedestrian injury risk, with higher population density associated with decreased risk. These findings are supported by several studies which associated densely-populated urban areas with decreased pedestrian injury risk and severity as pedestrians are more numerous and vehicle speeds are lower (Clifton et al., 2009; Ewing & Dumbaugh, 2009; Mohamed et al., 2013; Moudon et al., 2011). Densely populated urban areas are characterized by roadway designs that hinder traffic flow and reduce vehicle speeds, such as narrow lanes and traffic-calming infrastructure (Ewing & Dumbaugh, 2009). Our measure of intersection infrastructure was significantly positively correlated with alcohol outlets. In other words, areas with more alcohol outlets had more safety infrastructure at intersections, indicating that intersection infrastructure may be more frequently located in areas with higher alcohol outlet counts and, thus, higher pedestrian injury counts. It is possible that intersection infrastructure is installed in reaction to instances of pedestrian injury. To prevent future pedestrian injuries in areas of high alcohol outlet concentration, tailored strategies such as enhanced street lighting, medians or traffic islands, skid-resistant surfaces, and highly responsive pedestrian-operated crossing signals may be advisable (Clifton et al., 2009; Corben et al., 1996; Schuurman et al., 2009).

Limitations

This study is cross-sectional and, therefore, does not allow for discussion of changes in the injury risk environment over time. Because of the financial and temporal limitations inherent in observational data collection (Bader et al., 2015; Rundle et al., 2011), we were unable to record observations of physical and social disorder or pedestrian safety infrastructure for every census block group. Consequently, we used kriging to estimate these values.

We were unable to consistently identify alcohol- or drug-involved pedestrian crashes based on EMS records. Drug and alcohol use indicators were recorded for only 23% (n=194) of injured pedestrians by EMS staff; positive indicators of substance use were present in a quarter of patients (n=53) when it was noted at all. We also did not have access to police crash reports which might have identified the intoxication status of the driver. It is possible that driver and/or pedestrian intoxication confounds the relationship between neighborhood pedestrian injury risk and location of alcohol outlets; however, this association has not been fully explored by previous research and presents an important avenue of inquiry for future studies.

Furthermore, neighborhoods with more alcohol outlets may be visited by people looking to purchase or consume alcohol, either by foot or by car, and the high relative risk of pedestrian injury in these neighborhoods may relate to this alcohol-related traffic (Gruenewald, 2007; Pollack et al., 2005). As we did not have access to the residential addresses of drivers or pedestrians, non-residents may be included in block group injury counts. However, previous studies have shown that the majority of pedestrians are struck within a mile of their home (Anderson et al., 2012; Haas et al., 2015), suggesting that injured pedestrians are representative of the neighborhoods in which they are struck. Further inquiry will elucidate the mechanisms by which alcohol outlets affect pedestrian injury risk.

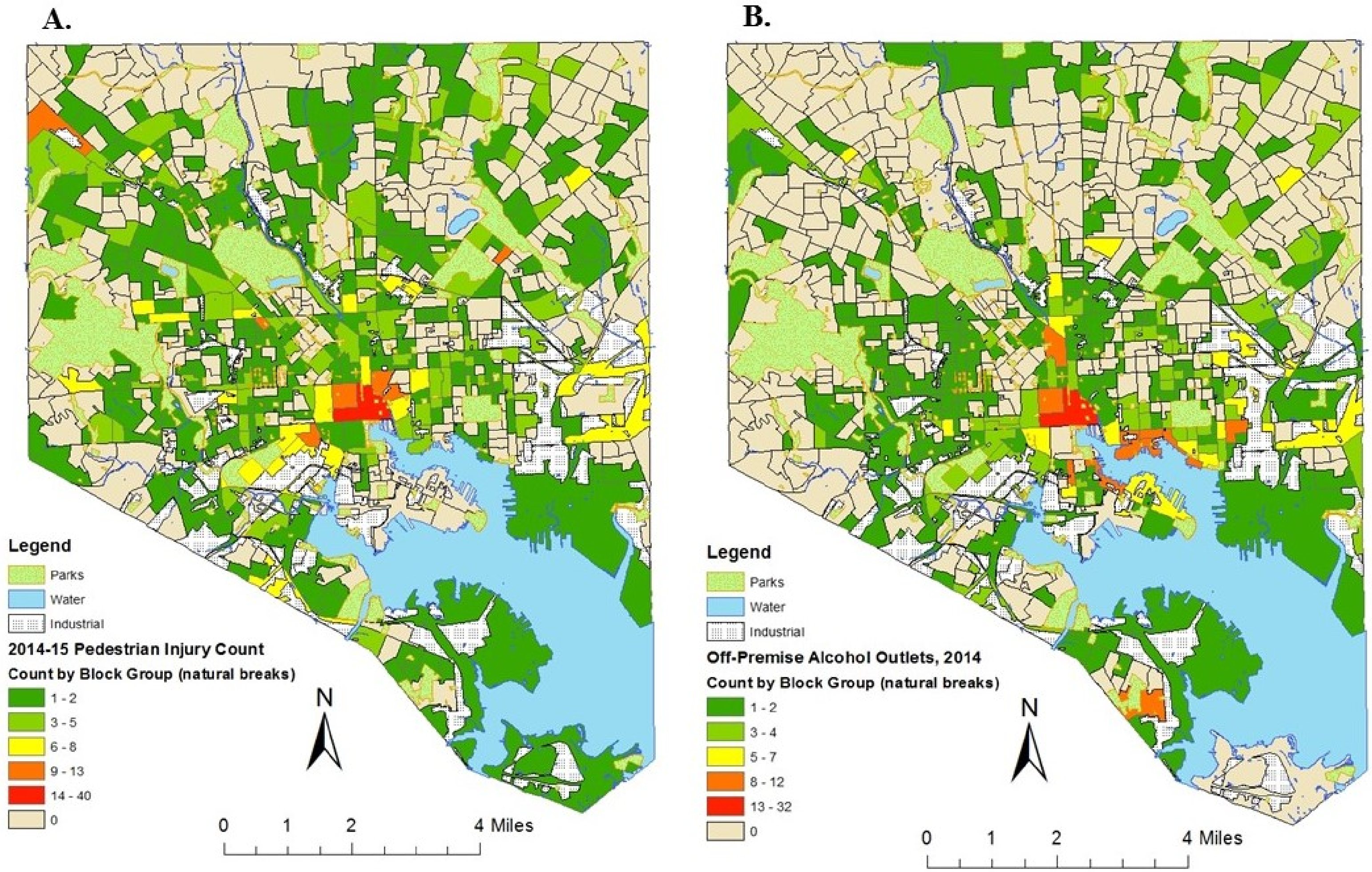
Conclusions

This study reinforces the importance of alcohol outlets in understanding neighborhood pedestrian injury risk and identifies new, malleable risk factors for pedestrian injury previously unexplored in the literature. The increased risk associated with alcohol outlets goes beyond what might be expected from established pedestrian injury risk factors such as traffic volume, population density, or socio-demographics. As previous research has largely focused on alcohol-involved crashes, our study adds to the evidence base by exploring the impact of neighborhood alcohol outlet concentration on all pedestrian injuries. This research provides important public health evidence for informing alcohol control policy decisions, particularly around liquor store licensing, zoning, and enforcement. A deeper understanding of the mechanisms by which alcohol outlets impact pedestrian injury risk will be essential for program planning and for creating targeted, evidence-based safety interventions.

Table 5.1. Description of selected characteristics by census block group (n=653)

Variable by Block Group	**N**	**Min.**	**Max.**	**Mean**	**SD**
Pedestrian Injury count	848	0	40	1.30	2.36
Alcohol Outlet count	693	0	32	1.06	2.13
Population density (per square mile in 1,000 residents)	--	0	95.16	13.72	9.94
Percent of all lots that are vacant (%)	--	0	49.53	7.02	9.65
Median Household income (in $1,000s)	--	0	224.43	44.81	27.72
Mean daily traffic volume (in 1,000 vehicles)	--	0.07	33.34	9.71	5.13
K-12 Schools count (public, private, special education)	239	0	4	0.37	0.65
Physical disorder score (range: 0-12)	--	0.21	8.89	4.30	1.92
Social activity score (range: 0-6)	--	0.44	3.02	1.43	0.50
Roadway infrastructure score (range: 0-8)	--	2.86	3.77	3.30	0.18
Intersection infrastructure score (range: 0-21)	--	1.29	10.21	3.84	1.96
Distance from downtown (miles)	--	0	7.5	3.32	1.59

Figure 5.1. Distribution of pedestrian injuries and alcohol outlets by census block group for Baltimore City, 2014



Map A: Count of pedestrian injuries from January 1, 2014 to April 15, 2015 by census block group (Data Source: Baltimore City Fire Department)
Map B: Count of off-premise alcohol outlets in 2014 by census block group (Dara Source: Baltimore City Board of Liquor License Commissioners)

Table 5.2. Univariate and multivariate results for spatial modeling (n=653)

Variable	**Unadjusted (RR)**	**p-value**	**Adjusted* (RR)**	**p-value**
Alcohol outlet count	1.211	<0.001	1.193	<0.001
Population density (per square mile in 1,000 residents)	0.985	0.0122	0.989	0.054
Percent of all lots that are vacant (%)	1.020	<0.001	1.023	<0.001
Median household income (in $1,000s)	0.992	<0.001	0.991	<0.001
Mean daily traffic volume (in 1,000 vehicles)	1.041	<0.001	--	--
Lagged traffic volume	1.100	<0.001	1.091	<0.001
Schools	1.107	0.244	--	
Physical disorder	1.045	0.144	--	
Social activity	0.985	0.893	--	
Roadway infrastructure	0.890	0.713	--	
Intersection infrastructure	1.174	<0.001	--	
Distance from downtown	0.792	<0.001	--	

Note: From negative binomial regression
*Adjusted for other covariates in the column

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CHAPTER 6. DISCUSSION

SUMMARY OF FINDINGS

Research Aim 1: Describe the prevalence and distribution of pedestrian injury in Baltimore City

Chapter 3 presented an investigation of city-wide pedestrian injury trends to assess injury risk among nationally-identified risk groups, as well as identify risk groups and locations specific to Baltimore City. A total of 699 pedestrians were involved in motor vehicle crashes from January 1 to December 31, 2014 in Baltimore City—an average of two EMS transports each day. The downtown neighborhood had the largest count of pedestrian injuries; the two adjoining block groups which make up the downtown district contained 36 and 13 injuries, respectively. The distribution of pedestrian injuries throughout the city did not coincide with population or income distributions, indicating there was not a consistent correlation between areas of concentrated population or concentrated poverty and areas of concentrated pedestrian injury.

Baltimore City's age-adjusted pedestrian injury rate is 1.13 per 1,000 population, almost twice the national rate of 0.61 per 1,000 population. Twenty percent (n=138) of all injuries occurred among children age 14 and younger, and 22% (n=73) of severe injuries occurred among young children. The rate of injury in this age group was 1.30 per 1,000 population, almost five times greater than the national average of 0.27 per 1,000. Almost 72% of all injured children were Black (n=99), and almost 89% of severely injured children were Black (n=55); this difference was not significant. The overrepresentation of Blacks among injured pedestrians in general, and children in particular, was not attributable to population distribution alone as the race-adjusted injury rate was almost twice the national average. Injury rates for adults age 65 and older were less than the national average.

Research Aim 2: Address the lack of a comprehensive database cataloging traffic safety infrastructure in Baltimore City

Chapter 4 detailed the creation and validation of the Inventory for Pedestrian Safety Infrastructure (IPSI) for both in-person observation and for use with Google Street View (GSV). GSV images are time-stamped with the month and year an image was processed, and many locations allow the user to travel back in time to every previous image taken at a location. The validation study was conducted at 172 liquor stores located across Baltimore City. In-person measures were collected from June to August 2015, while GSV measures were collected from February to March 2016. The IPSI is evidence-based and includes three domains: roadway features, midblock features, and intersection features.

The majority of items had good or excellent levels of inter-rater reliability (ICC≥0.8). For roadway features, bus stops (ICC=0.813, 95%CI=(0.763, 0.855)) and one-way streets (ICC=0.936, 95%CI=(0.918, 0.950)) showed the highest reliability across raters, while presence of street lights, alley streets, driveways and speedhumps showed moderate agreement with ICCs between 0.60 and 0.65. Sidewalk maintenance reliability was consistently the lowest measure across raters. Intersection features were particularly strong with most features showing ICCs above 0.80 across raters; these included crosswalks, traffic lights, stop signs, yield signs, pedestrian crossing signals, and set-back street stop lines. The majority of midblock safety features were not observed, with the exception of traffic circles and pedestrian crossing signs.

Two scales were also developed using Exploratory Factor Analysis, and both showed strong internal consistency. The intersection scale included crosswalks, traffic lights, signalized pedestrian crossing, set-back stop lines (Cronbach's alpha=0.86). There was less correlation among roadway features, which also produced one distinct scale: number of street lanes, presence of driveways, type of parking, presence of bus stops (Cronbach's alpha=0.60). The IPSI provides a valid, economically efficient tool for assessing pedestrian safety infrastructure that can be employed for a variety of research and urban planning needs. It can also be used for in-person or GSV observation.

Research Aim 3: Investigate the impact of the neighborhood presence of alcohol outlets on pedestrian injury

Chapter 5 explored the impact of alcohol outlets on the neighborhood relative risk of pedestrian injury, as well as the contribution of neighborhood disorder to pedestrian injury risk. A spatial analysis was conducted on census block groups in Baltimore City. Data included pedestrian injury EMS records from January 1, 2014, to April 15, 2015 (n=858), off-premise alcohol outlet locations for 2014 (n=693), and neighborhood disorder indicators and demographics. Negative binomial regression models were used to determine the relationship between alcohol outlet count and pedestrian injuries, controlling for other neighborhood factors. Spatial correlation was assessed and regression inference adjusted accordingly.

Each one-unit increase in the number of alcohol outlets was associated with a 19.3% (95% CI=(1.146, 1.245)) increase in the relative risk of neighborhood pedestrian injuries, adjusting for traffic volume, population density, percent of vacant lots, and median household income. The association between alcohol outlets and neighborhood pedestrian injury risk was unaltered by removing the block group with the highest count of alcohol outlets and pedestrian injuries. The attributable risk of pedestrian injury to alcohol outlets was 18.8% (95% CI=(16.1, 21.5)) or 155 extra injuries over baseline.

Percent of vacant lots was a strong predictor of neighborhood pedestrian injury risk with each increasing percent of vacant lots in a neighborhood associated with a 2.3% (95%CI=(1.014, 1.032)) increase in injury risk. Vacant lots have not been included in previous studies of neighborhood pedestrian injury risk, but they are important indicators of neighborhood physical disorder. Traffic volume was also a consistently strong predictor of pedestrian injury risk. With every increase in 1,000 vehicles, neighborhood pedestrian injury risk increased by 9.1% (95%CI=(1.059, 1.126), $p<0.001$). Median household income was protective of neighborhood pedestrian injury risk, with every $1,000 increase in median income associated with a 0.9% (RR=0.991, 95%CI=(0.988, 0.995), $p<0.001$) decrease in neighborhood pedestrian injury risk. Population density was marginally statistically significant; every increase in 1,000 people per square mile was associated with a 1.1% decrease in neighborhood pedestrian injury risk (RR=0.989, 95%CI=(0.980, 0.998), $p=0.054$). Pedestrian safety infrastructure measures and measures of social activity were not significant predictors of pedestrian injury risk when controlling for other neighborhood factors.

CONCLUSIONS

Taken as a whole, this research suggests new and understudied mechanisms underlying neighborhood pedestrian injury risk. Studies examining trends in pedestrian injury and fatality have been focused largely at the national level, and localized studies of pedestrian injury have been scarce. Reliance on national trend data without localized research on pedestrian injury risk factors may cause researchers to target resources to locations or populations who are not at high risk for pedestrian injury. The research described in Chapter 3 identifies locations and risk groups unique to Baltimore City while also recognizing the importance of national trend data in informing research questions and identifying risk groups for investigation. In Baltimore City, the need for safety strategies is particularly important as there are 25 new residential development projects underway in the downtown district alone—the neighborhood with the highest pedestrian injury count and highest count of alcohol outlets (Papagani, 2016).

As the urban landscape and associated pedestrian behavior continue to transform, investigation of local and street-level risk factors is necessary for ensuring pedestrian safety and evolving public health prevention strategies. Reliable and valid measurement of pedestrian safety infrastructure is necessary to effectively investigate pedestrian injury risk factors. However, creating and maintaining a comprehensive database of a city's traffic safety infrastructure can be cumbersome and costly (Mooney et al., 2016; Rundle et al., 2011). The IPSI fills an important need by providing an inexpensive, easy-to-use, evidence-based assessment of pedestrian safety infrastructure. The IPSI was employed to assess roadway and intersection infrastructure in Chapter 5, allowing for the investigation of potential pedestrian injury risk factors that would not have been covered by existing data sources. This tool allows researchers the ability to quickly and economically make street-level observations to address a variety of research and urban planning needs.

While investigation of local pedestrian injury trends is important, identifying neighborhood risk factors which may be generalizable to other metropolitan areas may lead to broad policy recommendations and more effective interventions to reduce pedestrian injuries (LaScala et al., 2004). Findings described in Chapter 5 suggest that there is a strong relationship between neighborhood presence of alcohol outlets and pedestrian injury risk in Baltimore City after controlling for selected neighborhood factors. Each increase in the number of alcohol outlets was associated with a 19.3% increase in the neighborhood relative risk of pedestrian injuries. The pedestrian injury risk attributable to alcohol outlets was 18.8% or 155 extra injuries. The findings in this dissertation reinforce the importance of alcohol outlets in understanding neighborhood pedestrian injury risk and provides important public health evidence for informing policy decisions about liquor store licensing, zoning, and enforcement.

Furthermore, this study identifies new, malleable neighborhood risk factors which may be targeted through policy and community interventions. Vacant lots were a strong predictor of neighborhood pedestrian injury risk that have not been widely studied as predictors of pedestrian injury in previous research. Vacant lots are an important indicator of neighborhood disorder and have significant effects on community health and safety (Branas et al., 2012; Kondo et al., 2016). A qualitative study of vacant lots' impact on community well-being found that vacant lots overshadowed positive aspects of the community, eroding community cohesion, attracting crime, and increasing residents' fear and anxiety (Garvin et al., 2013). Vacant lot remediation has been shown to significantly decrease violent crime (Branas et al., 2016; Kondo et al., 2016); addressing vacant lots may also significantly impact neighborhood pedestrian injury risk.

STRENGTHS AND LIMITATIONS

This research extends the evidence base in support of alcohol outlets and the neighborhood alcohol environment as a critical risk factor for a variety of public health problems. Previous research on the neighborhood alcohol environment has largely focused on violent injury or alcohol-involved motor vehicle crashes. This is one of the few studies to examine the impact of alcohol outlets on pedestrian injury risk for both sober and intoxicated pedestrian crashes.

The methods used in this research are also a significant strength. This research used leading methods in the fields of GIS, spatial statics, and environmental observation to address this understudied but important area of public health. Only a handful of studies have looked at the impact of alcohol outlets on pedestrian injury risk, and much of this work aimed to establish the relevance of the physical environment to the geographic distribution of pedestrian injury and to tackle the methodological issues in data analysis (LaScala et al., 2001; Pulugurthaa et al., 2007). Furthermore, many of these studies neglected to account for potential spatial variation when assessing the relationship between the neighborhood alcohol environment and pedestrian injury risk.

There is also little research exploring the social environment's impact on pedestrian injury. When the social environment is taken into account, pedestrian injury studies have focused largely on sociodemographic measures such as income, level of education, or employment status and not on observable measures of social disorder. To date, no other study has examined the cumulative impact on pedestrian injury of alcohol outlets and features of the physical and social environment. By including observational measures of the physical and social environment, the study design attempted to control for possible risk factors unmeasured in previous studies.

Finally, this study provides a reliable, economically-efficient tool for assessing pedestrian safety infrastructure that can be employed for a variety of research and urban planning needs. No comprehensive database cataloging Baltimore City's traffic safety infrastructure exists, in part because of the logistical and methodological challenges in maintaining such a database (City of Baltimore Department of Transportation, 2015; Mooney et al., 2016; Rundle et al., 2011). As with previous evaluations of observational tools to assess the built environment, GSV provided a reliable alternative to in-person street audits for safety infrastructure and produced relatively quick turn around on data collection (Mooney et al., 2016; Rundle et al., 2011). GSV allows for a wider area to be surveyed compared to in-person audits without the need for additional resources or time (Clarke et al., 2010). The IPSI fills an important gap by providing an inexpensive, easy-to-use, evidence-based tool to assess the presence (or absence) of pedestrian safety infrastructure.

Limitations

This research is cross-sectional and, therefore, does not allow for discussion of changes in the pedestrian injury risk environment over time. Because EMS data could not be linked with hospital records, pedestrian outcomes after transport to the emergency department are unknown; therefore, this research does not discuss pedestrian fatality in particular but pedestrian injury in general. Demographic features were recorded based on EMS staff perception and not based on self-report by the patient; it is possible that certain demographic characteristics such as sex or race were mislabeled.

A description of the circumstances surrounding each injury was also not available, limiting the ability to draw conclusions about injury mechanisms or make recommendations for targeted injury prevention strategies. Police accident reports commonly have been used in previous pedestrian injury studies to identify crash characteristics and risk factors (Clifton et al., 2009; DiMaggio & Durkin, 2002; Mohamed et al., 2013; Nicaj et al., 2006; Pour-Rouholamin & Zhou, 2016). However, a San Francisco study found that the Statewide Integrated Traffic Reporting System compiled by California Highway Patrol under-reported pedestrian injuries among Blacks and men, as well as less severe injuries (Sciortino et al., 2005). Paramedics are not required to alert police when they treat a person struck by a motor vehicle; consequently, some pedestrians may be reluctant to summon police and file a report when the police are not initially present at the scene of a crash (Sciortino et al., 2005). It is possible that EMS records would be more complete for a wider range of injuries, as well as injuries which occur among certain minority groups, compared to police reports. EMS data have been used in previous analyses of non-violent injuries (Newgard et al., 2011; Warden et al., 2010).

Pedestrian and driver residence was also unknown, limiting the ability to draw conclusions about length and duration of exposure to neighborhood pedestrian injury risk factors. Neighborhoods with more alcohol outlets may be visited by people looking to purchase or consume alcohol, either by foot or by car, and the high relative risk of pedestrian injury in these neighborhoods may relate to this alcohol-related traffic (Gruenewald, 2007; C. E. Pollack et al., 2005). As we did not have access to the residential addresses of drivers or pedestrians, non-residents may be included in block group injury counts. However, previous studies have shown that the majority of pedestrians are struck within a mile of their home (Anderson et al., 2012; Haas et al., 2015), suggesting that injured pedestrians are representative of the neighborhoods in which they are struck. Further inquiry will elucidate the mechanisms by which alcohol outlets affect pedestrian injury risk. Future research could also include measures of neighborhood walkability, which would further account for exposure to neighborhood risk factors (Mooney et al., 2016).

Substance use indicators were not consistently included in EMS records, limiting the ability to identify alcohol- or drug-involved pedestrian crashes. Drug and alcohol use indicators were recorded for only 23% (n=194) of injured pedestrians by EMS staff; positive indicators of substance use were present in a quarter of patients (n=53) when it was noted at all. The intoxication status of the driver was also unknown. It is possible that intoxication confounds the relationship between neighborhood pedestrian injury risk and location of alcohol outlets. However, this association has not been fully explored by previous research. Furthermore, the exclusion of this variable does not pose a significant methodological limitation as the study's focus is on environmental risk and not on individual risk. This limitation is further outweighed by the dearth of evidence in this area and the need for preliminary investigations establishing the relationship between the alcohol environment and pedestrian injury.

IMPLICATIONS FOR PUBLIC HEALTH POLICY AND PRACTICE

The findings described in this dissertation have important implications for public health policy and practice. Alcohol outlet zoning and licensure and pedestrian injury prevention are both currently topics of important debate in Baltimore City (Broadwater, 2016; Ericson, 2016; Meisel et al., 2015; K. M. Pollack et al., 2014). While the number of Baltimore's licensed liquor outlets has decreased from an all-time high in 1968, Baltimore City still bears a disproportionate burden of ills relating to alcohol availability, including motor vehicle crashes, assaults, and alcoholism-related morbidity and mortality (Baltimore City Department of Planning, 2009; LaVeist & Wallace, 2000). This study adds to the evidence base on the deleterious effects of alcohol outlets to neighborhood health and well-being, helping public health advocates and elected officials implement effective, evidence-based policy. Reducing the number of liquor stores has been shown to result in reductions in violent injury (Jennings et al., 2014). The findings from this dissertation add to the evidence in favor of reducing the number of liquor stores by demonstrating the neighborhood risk of pedestrian injury attributable to alcohol outlets.

This dissertation also has important implications for creating targeted community-level behavioral health interventions addressing neighborhood pedestrian injury risk factors around alcohol outlets beyond patterns of alcohol consumption. This research identified communities and neighborhoods within Baltimore City that are unduly burdened by pedestrian injury. The neighborhood with the highest count of pedestrian injuries and alcohol outlets, the downtown district, will need particular attention as residential and commercial development increases in this neighborhood (Papagani, 2016). Furthermore, the study has identified specific neighborhood characteristics such as vacant lots that can be targeted to improve the pedestrian injury risk environment. Current research on vacant lots identifies vacant lot remediation as an important community-level intervention in reducing gun violence and other crime (Branas et al., 2016; Kondo et al., 2016). Remediation strategies include transformation of vacant lots into community gardens, green stormwater management sites, or other public-use sites such as putting greens or athletic fields (Kondo et al., 2016). In Youngstown, Ohio, the remediation program resulted in statistically significant reductions in felony assault, burglaries, and robberies in neighborhoods where it was implemented (Kondo et al., 2016). Remediation schemes in Philadelphia also saw sustained reductions in gun violence over several years, and remediation was found to be more cost effective compared to other violence-prevention programs (Branas et al., 2016). The effects of vacant lot remediation on pedestrian injury have not been previously studied. Future studies will be designed that elucidate the mechanisms by which community-level physical and social environment factors around alcohol outlets result in increased pedestrian injury.

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APPENDICES

APPENDIX A. DISCUSSION OF DATA SOURCES

Pedestrian Injury Data

Baltimore Data Source: Baltimore City Fire Department Emergency Medical Services data, all calls designated "pedestrian injury."

Pedestrian injury incidence data were collected by emergency medical services (EMS) records from January 1, 2014, to April 15, 2015 (n=848). The Baltimore City Fire Department (BCFD) operates the City's EMS system, which deploys paramedics in response to all calls within the city limits (Knowlton et al., 2013). When an emergency call is received, Dispatch administers a brief set of questions to the caller to determine the severity of the patient condition, then asks the patient's location; Dispatch then relays the message to paramedics. Once on the scene, paramedics evaluate the patient and fill out the EMS patient report that includes the code for pedestrian injury. Paramedics recorded patient and other incident-related data on wireless tablet computers using proprietary software that was developed in compliance with the Electronic Maryland Ambulance Information System (Knowlton et al., 2013). Patient information included demographics; destination and patient disposition; patient priority; indicators of drug or alcohol use; and paramedic-reported impression of the primary health problem.

Ambulances are routinely sent to precise locations of injured persons, allowing for the geographic mapping of injury events (Cusimano et al., 2010; Ryb et al., 2007). Furthermore, EMS data provide a measure of when an injury occurred in addition to the injury location, allowing for examination of temporal variation in injury risk (Cusimano et al., 2010). As Baltimore City's residents are served by a single EMS system, these data are representative of all EMS calls for pedestrian injuries (Cusimano et al., 2010).

National Data Source: Centers for Disease Control and Prevention's WISQARS Injury Statistics Query and Reporting System

Fatal injury reports show the total number of injury deaths and death rates by intent and mechanism or cause of injury, geographic region/state, race/ethnicity, sex, and age. Fatal injury data are collected through CDC's National Center for Health Statistics' (NCHS) National Vital Statistics System (NVSS) (National Center for Injury Prevention and Control, 2016). Data are collected through contracts between NCHS and vital registration systems operated in various jurisdictions legally responsible for the registration of vital events, including births, deaths, marriages, divorces, and fetal deaths (Centers for Disease Control and Prevention, 2016). There are 57 vital registration jurisdictions in the United States. Detailed information on the collection and dissemination of vital records can be found in *Vital Statistics* (Schwartz, 2009).

Nonfatal injury reports provide national estimates of injuries treated in U.S. hospital emergency departments (ED) by intent and mechanism or cause of injury, race/ethnicity, sex, and disposition when released from the ED (categories include hospitalized, moved for specialized care, treated and released). Non-fatal injury data are collected through the National Electronic Injury Surveillance System All Injury Program (NEISS-AIP), operated by U.S. Consumer Product Safety Commission in association with CDC's National Center for Injury Prevention and Control (NCIPC) (National Center for Injury Prevention and Control, 2016). NEISS is a national probability sample of hospitals in the U.S. and affiliated territories. Patient information is collected from each participating NEISS hospital for every emergency visit involving an injury associated with consumer products—in this case, motor vehicles. From this sample, the total number of product-related injuries treated in hospital emergency rooms nationwide can be estimated (U.S. Consumer Product Safety Commission, 2016).

Other Data Sources: National Highway Safety Administration (NHTSA) Pedestrian Safety Factsheet for 2014

Fatal crash data were taken from the Fatality Analysis Reporting System (FARS), a census of fatal crashes within the 50 States, the District of Columbia, and Puerto Rico (although Puerto Rico is not included in U.S. totals). Non-fatal injury statistics are based on data from the National Automotive Sampling System (NASS) General Estimates System (GES). The NASS GES is a probability-based sample of police-reported crashes, from 60 locations across the country, from which estimates of national totals for non-fatal injury are derived (National Center for Statistics and Analysis, 2016). Both systems are administered by NHTSA.

Alcohol Outlet Data

Locations of alcohol outlets in 2014 were obtained through the Baltimore City Board of Liquor License Commissioners (n=1,338). There are 12 liquor license types administered by the Board. This study focused on the four licensure classes concerned with sale of package goods for off-premise consumption—liquor packaged goods stores, bars/taverns, and wine and beer only stores (n=693) (Campbell et al., 2009; Milam et al., 2014). On- and off-premise outlets differentially impact injury risk. Off-premise outlets are more strongly associated with drinking problems, crime, and violence compared to outlets licensed for on-premise consumption only (Branas et al., 2011; Furr-Holden et al., 2016;

Schonlau et al., 2008). Restaurants, hotels/motels, entertainment venues, and non-profit private clubs were not included in this study as these establishments only allow on-premise alcohol consumption.

Vacant Lots

Addresses for all vacant lots in Baltimore City in 2015 were compiled by the Baltimore City Housing Authority (City of Baltimore, n.d.). Digital parcel maps of all lots in Baltimore City were available through the Maryland State Department of Planning (Maryland Department of Planning, n.d.). To calculate percent of vacant lots per block group, we aggregated the count of vacant lots and the count of all lots to each block group. We then divided the total number of lots by the number of vacant lots. Vacant lots are an important indicator of neighborhood disorder and have significant effects on community health and safety (Branas et al., 2012; Kondo et al., 2016). A qualitative study of vacant lots' impact on community well-being found that vacant lots overshadowed positive aspects of the community, eroding community cohesion, attracting crime, and increasing residents' fear and anxiety (Garvin et al., 2013). Residents also felt significant stigma associated with living in a disordered neighborhood and felt unfairly judged by outsiders, further contributing to self-reported sadness and depression (Garvin et al., 2013).

Traffic Volume

Traffic volume is an important predictor of pedestrian injury risk (Lassarre et al., 2007; Morency et al., 2012). Average Daily Traffic Volume for 2013 was collected by the Maryland State Highway Administration's Traffic Monitoring System (Maryland State

Highway Administration, n.d.). Traffic counts are recorded at a specific point on the roadway referred to as a “count station” or “site” but extrapolated to represent the entire segment or section of roadway by a linear referencing system (LRS) integration process. This data is then mapped for use as both a point file and a segment file. There are 752 counting stations in Baltimore City; we removed 168 counting stations located on highways and interstates to create a measure of traffic volume for residential roadways (n=584). For this study, we used Annual Average Daily Traffic (AADT) to include a measure of weekend traffic flow. Annual Average Daily Traffic is the number that represents a typical traffic volume number any time or day of the year at a site.

We used ArcGIS 10.4 to join segment data to each block group to create an average measure of the average daily traffic flow through each block group. Six block groups had no recorded traffic observation. For these block groups, we assigned the value from the nearest collection station to the block group. The smallest distance from a block group to a collecting station was 0.17 ft and the longest was 148.2 ft. We surmise that these block groups were not assigned values by ArcGIS because of a geocoding error and not because the lacked traffic flow.

Schools

A list of all public, private, charter, and special education schools in 2015 for grades K-12 was compiled through the Maryland State Department of Education and the Baltimore City Public Schools (Baltimore City Public Schools, n.d.; Maryland State Board of Education, n.d.) (n=239). A Florida study found that a majority of pedestrian crashes involving school-aged children (age 4 to 18) occurred within a half-mile of a school, and middle- and high school-aged children were more involved in crashes near schools that elementary school-aged children (Abdel-Aty et al., 2007). Research on pedestrian injuries around schools has shown that numbers of injuries were greater around schools located in areas with higher youth population densities, more unemployment, fewer high-income households, and greater traffic flow (LaScala et al., 2004). However, a Vancouver study found that schools were not associated with pedestrian injury hotspots, potentially because of increased protective road safety engineering and infrastructure around schools (Schuurman et al., 2009).

Safe Routes to School: The goal of the Safe Routes to School (SRTS) Program is to improve the safety of children who walk or bicycle to school and to promote these types of transportation. Parents and administrators at the school work along with other community groups and agencies to build new sidewalks, improve pedestrian crossings, teach children safer bicycling and walking skills and promote healthier, more active lifestyles (Maryland State Highway Administration, 2016). The expansion of SRTS was announced for the beginning of the school year in 2014 (Baltimore City Office of the Mayor, 2014). As of 2016, 130 public elementary and middle schools across Baltimore City have incorporated some aspect of SRTS (Department of Transportation, 2016). For the environmental component, the Lime Green Footprint Installation project, the Department of Transportation identified the best routes for walking in school neighborhoods and installed footprints on selected sidewalks as guides. During fiscal year 2013-14, five schools installed this component of the program, with an additional seven schools installing the footprints in FY 2014-15 (Department of Transportation, 2016). Because almost all public elementary and middle schools have incorporated aspects of

SRTS, and expansion of the program occurred during our study period, we have not included SRTS in this study.

Neighborhood Data

Assessments of the neighborhood environment were obtained using The Neighborhood Inventory for Environmental Typology (NIfETy) Instrument. NIfETy is a standardized inventory designed to assess characteristics of the neighborhood environment related to violence, alcohol, and other drug (VAOD) exposures (Milam et al., 2014). The NIfETy Instrument included 75 items operationalized into seven domains: physical layout, types of dwellings, adult activity, youth activity, physical order and disorder, social order and disorder, and VAOD indicators (Furr-Holden et al., 2008). The NIfETy has strong psychometric properties; the ICC for the total scale is 0.84, 0.71 for the VAOD scale, and 0.67 to 0.79 across raters (Furr-Holden et al., 2010). Validity metrics are also strong (Furr-Holden et al., 2010).

Eighteen binary items from the NIfETy instrument were used to classify the neighborhood physical and social environment. These items were selected because they have been used in previous investigations of the neighborhood environment (Cohen et al., 2003; Furr-Holden et al., 2015; Perkins & Taylor, 1996; Sampson, 1997). Twelve of the items were used to classify the neighborhood physical environment: broken windows; abandoned buildings; vacant houses; vacant lots; unmaintained properties; broken bottles; graffiti; evidence of vandalism; presence of intoxicated people, signs of using alcohol/drugs or signs of drug selling; syringes or vials; baggies, blunt guts/wrappers or pot roaches; alcohol bottles. Six items were used to classify the neighborhood social environment: youth playing, youth sitting in a group, youth in transit, positive adult interactions, adults sitting on steps, adults watching youth. Items were summed to create two scales of neighborhood environment; the Cronbach's alpha was 0.79 for the physical environment scale and 0.66 for the social activity scale.

We aggregated the physical disorder and social activity scales to the Census block group level in ArcGIS 10.4. Because of the small size of Census block groups and the financial and temporal limitations of street sampling, 123 (18.8%) block groups lacked measures. To estimate the values for the missing block groups, we performed ordinary kriging in R to estimate a city-wide map of values for each of the four scales (Waller & Gotway, 2004). Using a planometric map of all Baltimore City streets, we then assigned a kriged value for each scale to each street centroid. We imported this street map into ArcGIS 10.4 and aggregated the centroid values to the block group level to calculate the average estimated score for each scale for each block group.

Street Block sample selection: For this analysis, we used data collected from July to November 2012, the last year city-wide data collection took place; data collection took place on a random sample of 802 blocks located throughout the city. Planometric data were obtained from the Baltimore City Mayor's Office of Information and Technology to generate maps of 272 neighborhood statistical areas; nonresidential neighborhoods (mainly industrial areas) and neighborhoods with fewer than 26 residents were eliminated (Furr-Holden et al., 2008). A random sample of census blocks within neighborhoods was selected, and unit blocks were then randomly selected from each census block (Furr-Holden et al., 2008). The number of blocks selected within each neighborhood was a function of the number of census blocks within each neighborhood (Furr-Holden et al., 2008). Streets categorized as “alleys,” “expressways,” or “ramps” through planometric data were eliminated from the sampling frame (Furr-Holden et al., 2008). Raters traveled to selected blocks to validate that they were inhabited; if the block was not residential or uninhabited (e.g. all houses appeared abandoned), a replacement block was selected until a ratable block was identified (Furr-Holden et al., 2008).

An additional sample of blocks was included to correspond to the addresses of participants in the Baltimore Prevention Program (BPP). The BPP is a longitudinal epidemiological study of high-risk Baltimore City youths who have been assessed annually from the fall of their entry into first grade to the present (Furr-Holden et al., 2008). Each annual assessment measures a variety of health and behavior factors, including VAOD exposure, anxiety and depression, injury, and neighborhood/community disadvantage (Furr-Holden et al., 2008). BPP participants were included in the sample to validate corresponding NIfETy measures such as VAOD exposure. When a BPP block was the same as a random census block, a different census block was randomly drawn from the same neighborhood (Furr-Holden et al., 2010). If more than one BPP youth lived on the same block, the same block ratings were used for all BPP youth residing on that block (Furr-Holden et al., 2010).

Baltimore City Demographic Data

We used 2010 Census population estimates for both national and Baltimore City age-, race- and gender-based population totals (U.S. Census Bureau, 2010). We also used 2010 Census data for median household income, population totals and population per square mile per block group. In a Canadian study, there was a statistically significant inverse relationship between median household income and average number of injured pedestrians in a census tract (Morency et al., 2012). Traffic volume was also higher in poorer census tracts versus wealthier census tracts (Morency et al., 2012).

Population density was calculated by taking the total population of each block group and dividing by the area of the block group in square miles.

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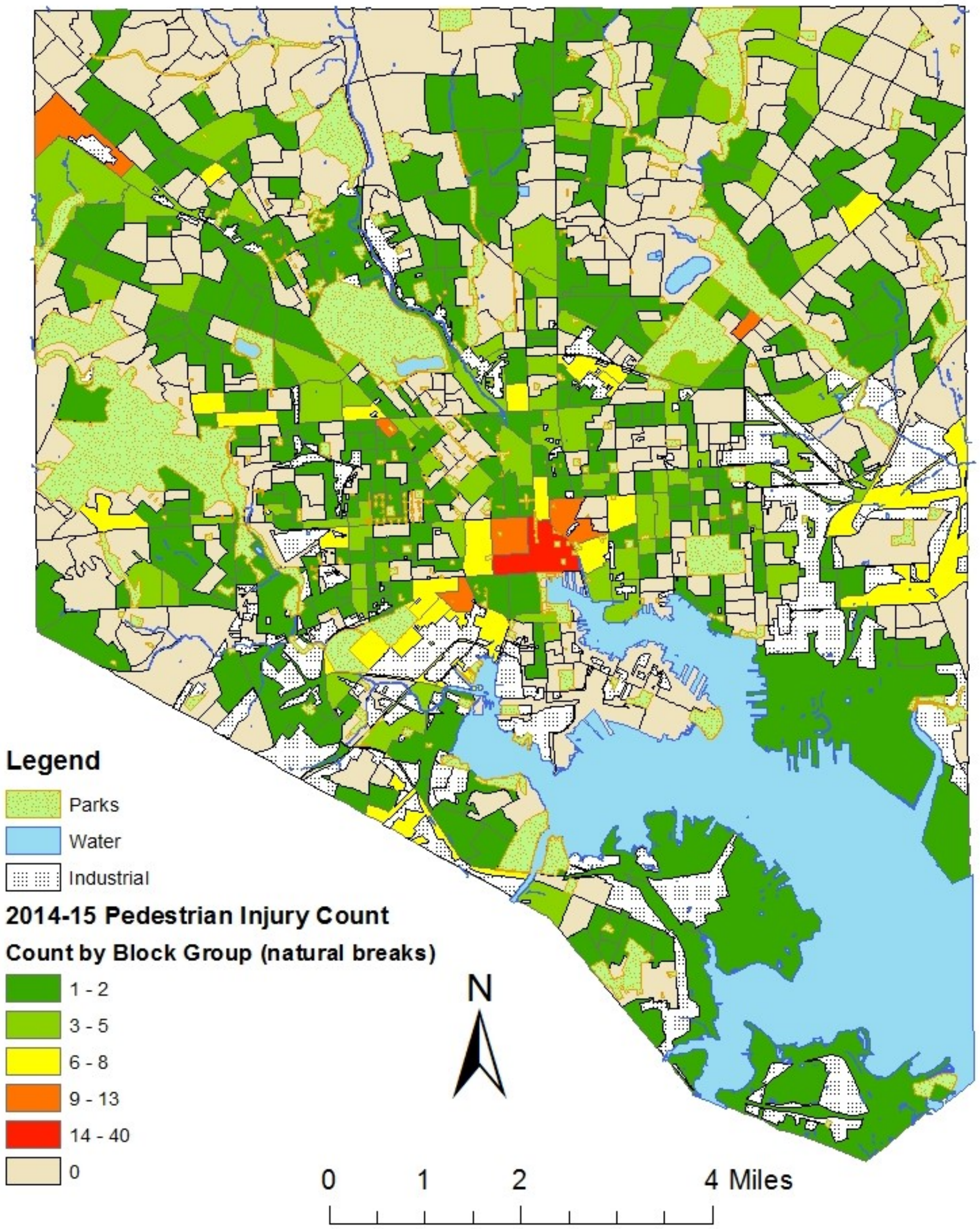
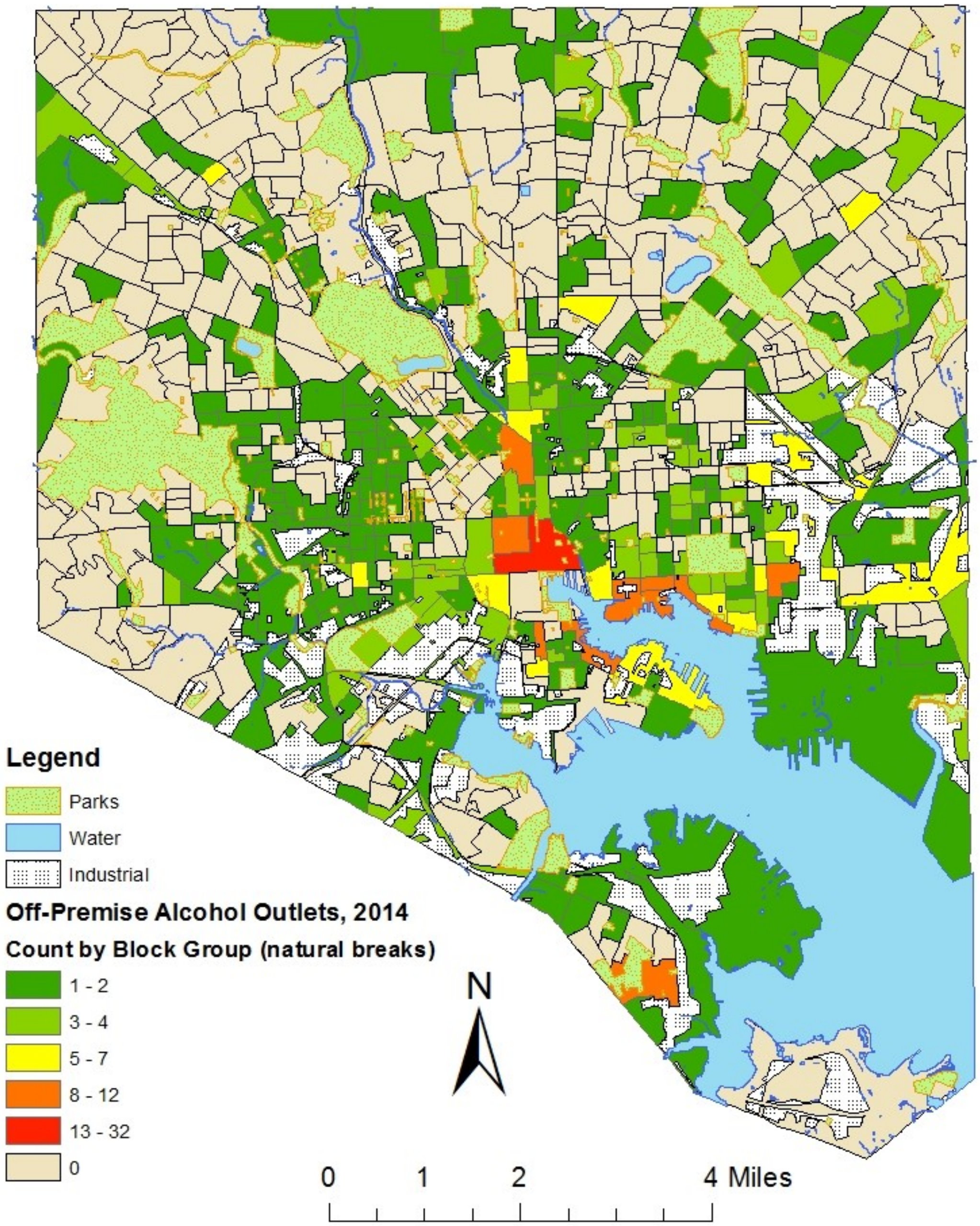
APPENDIX B. MAPS OF STUDY VARIABLES

B.1. Count of Pedestrian Injuries by Block Group, Baltimore City, January 1, 2014-April 15, 2015



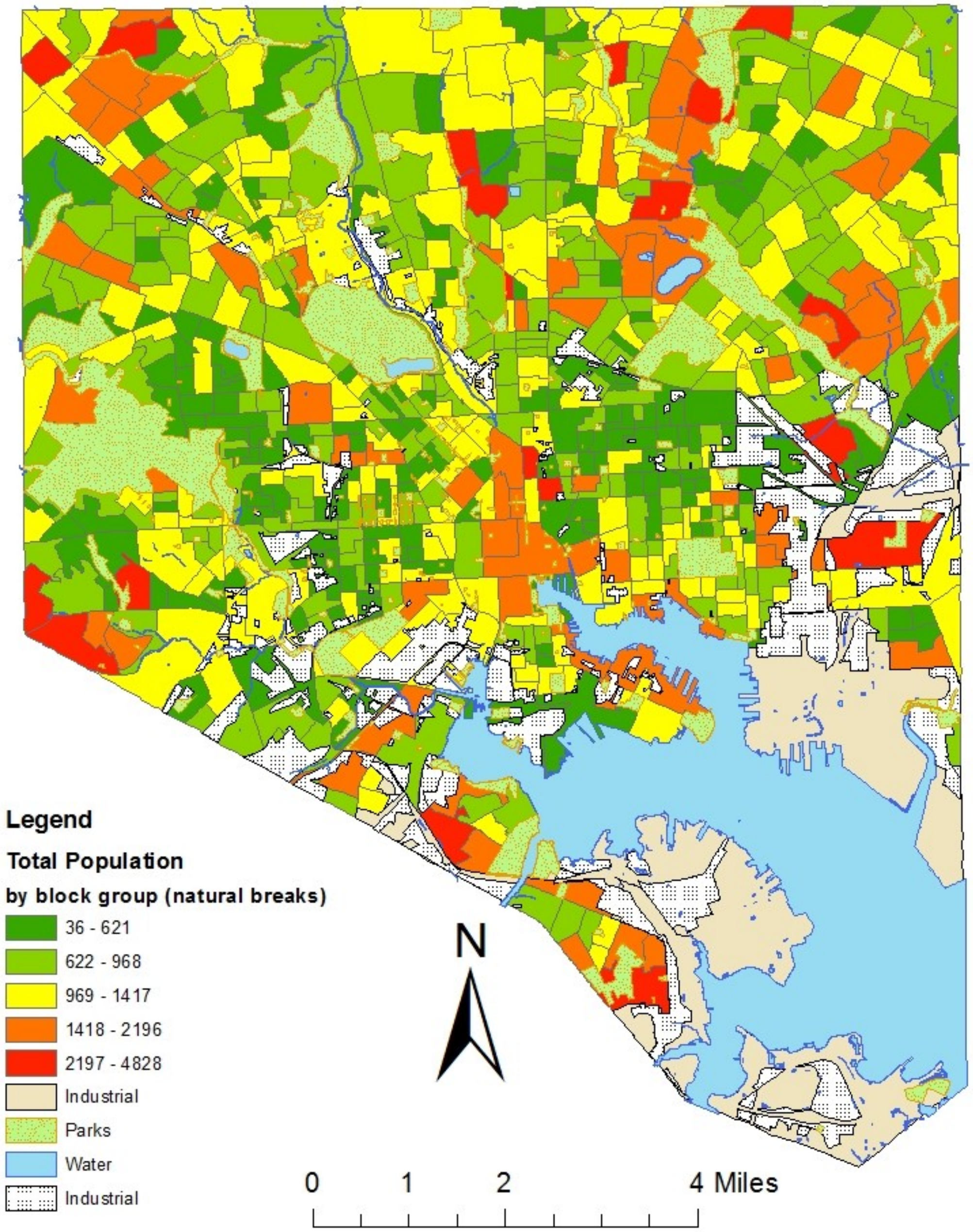
Data source: Baltimore City Fire Department Emergency Medical Services

B.2. Count of Off-Premise Alcohol Outlets by Block Group, Baltimore City 2014



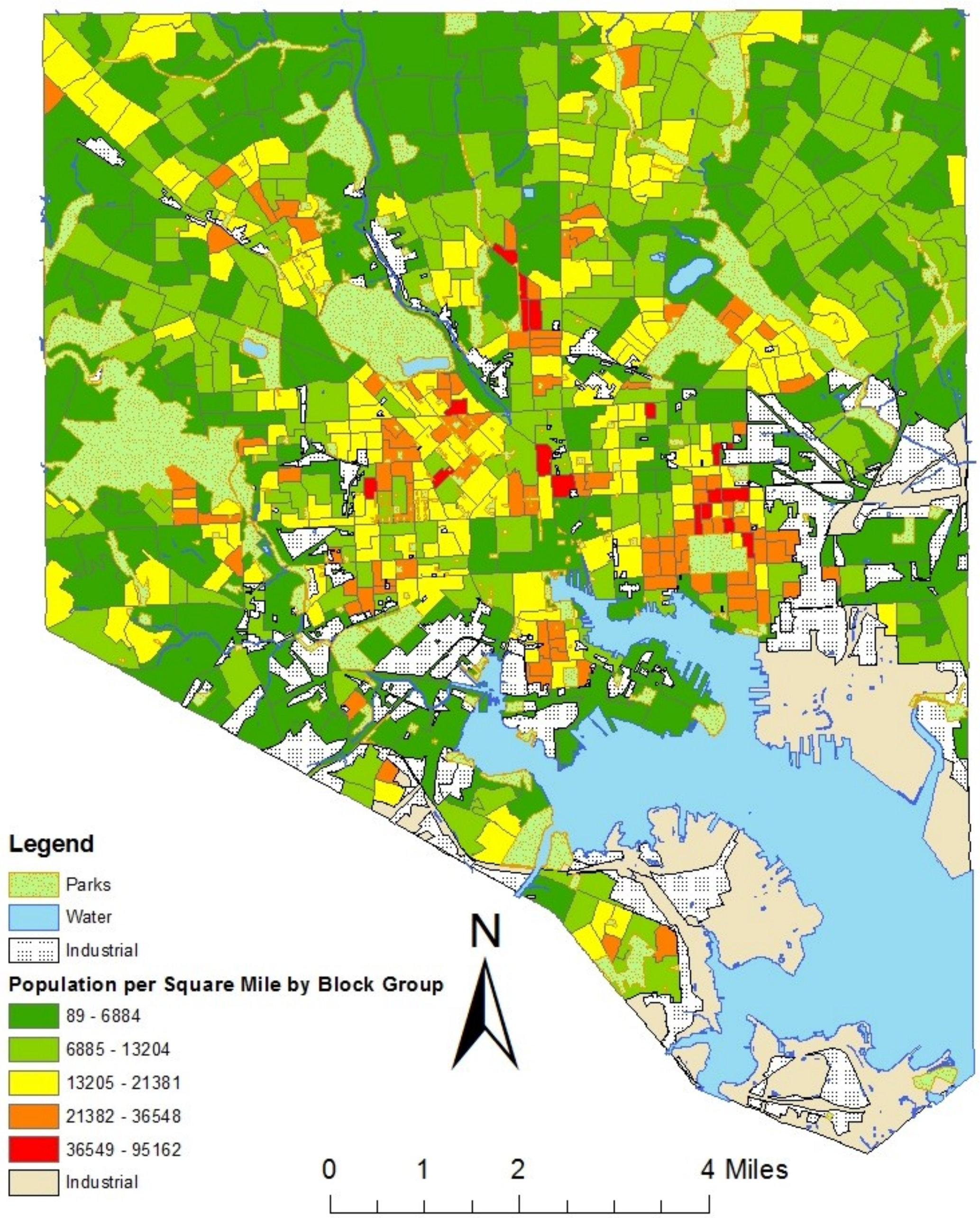
Data source: Board of Liquor License Commissioners for Baltimore City, 2014

B.3. Count of Total Population by Block Group, Baltimore City 2010



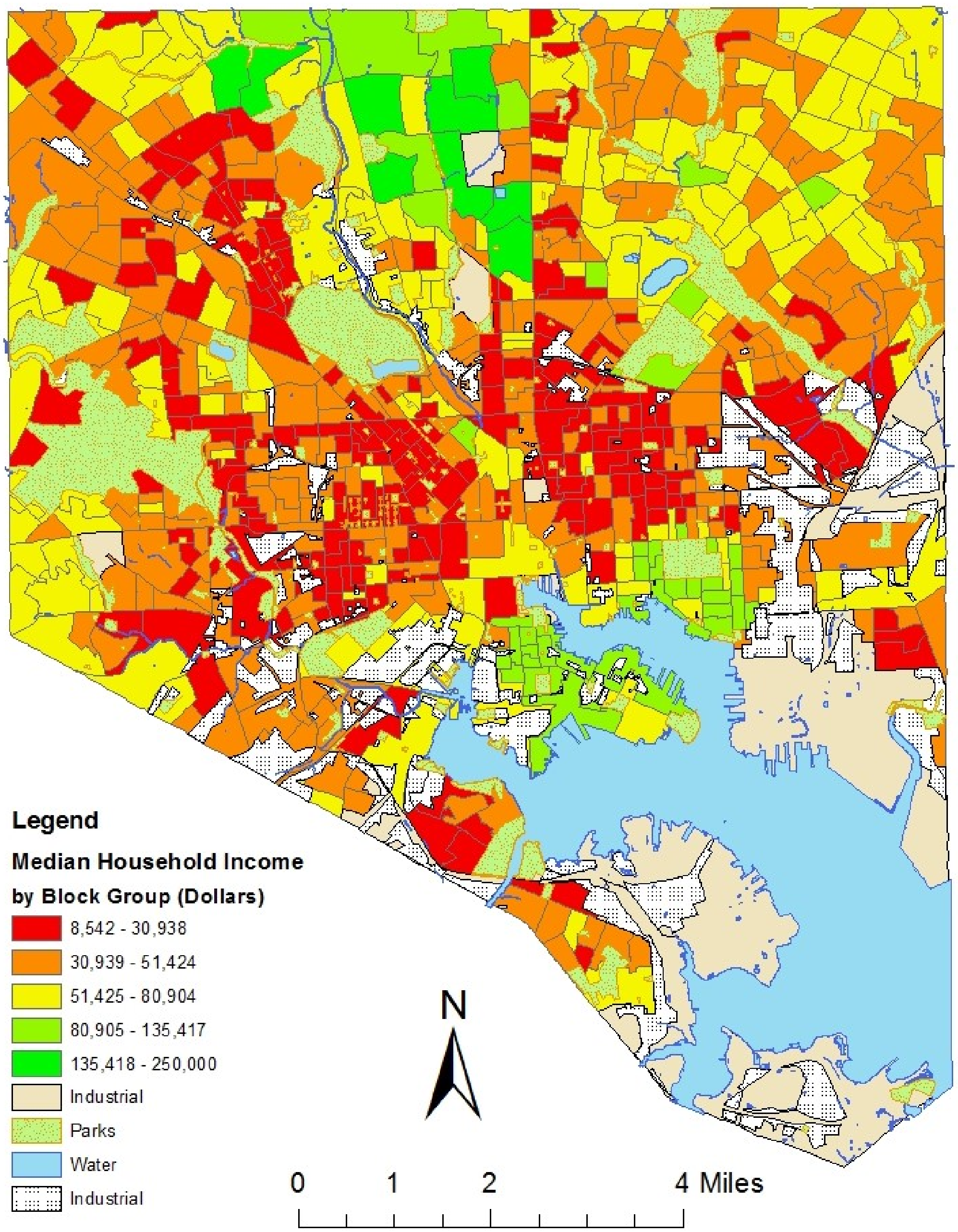
Data source: United States Census, 2010

B.4. Total Population per Square Mile by Block Group, Baltimore City 2010



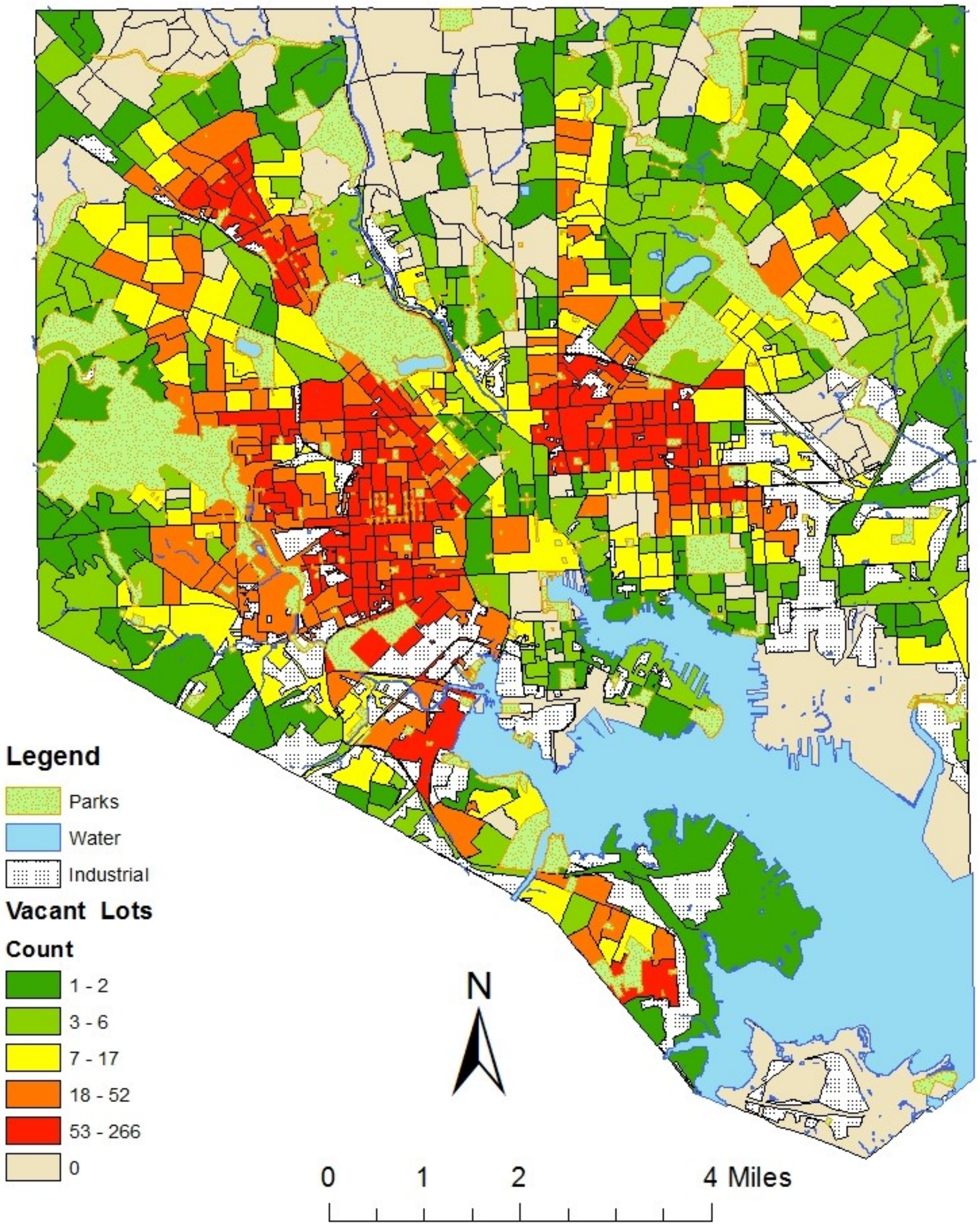
Data source: United States Census, 2010

B.5. Median Household Income by Block Group, Baltimore City 2010



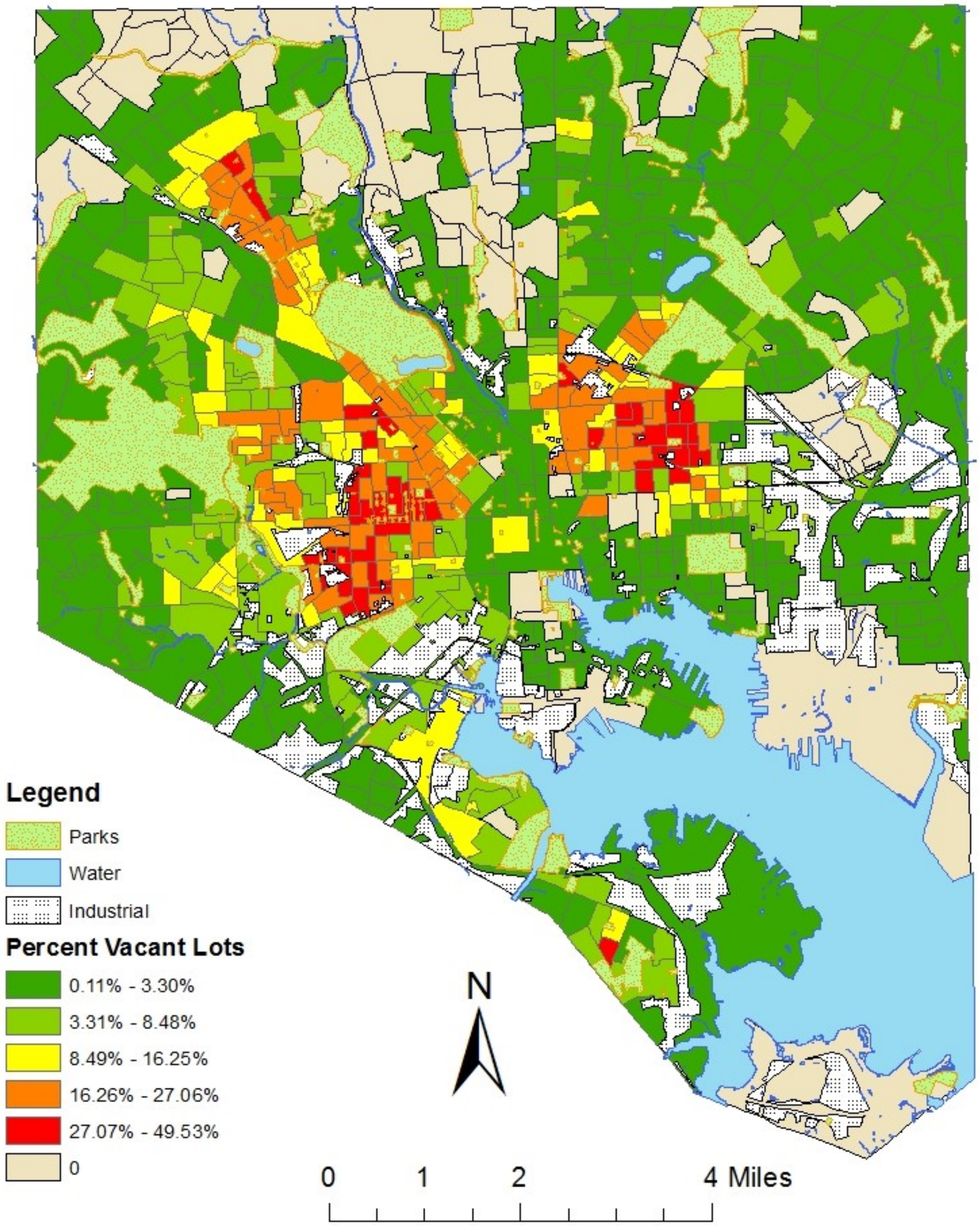
Data source: United States Census, 2010

B.6. Count of Vacant Lots by Block Group, Baltimore City 2015



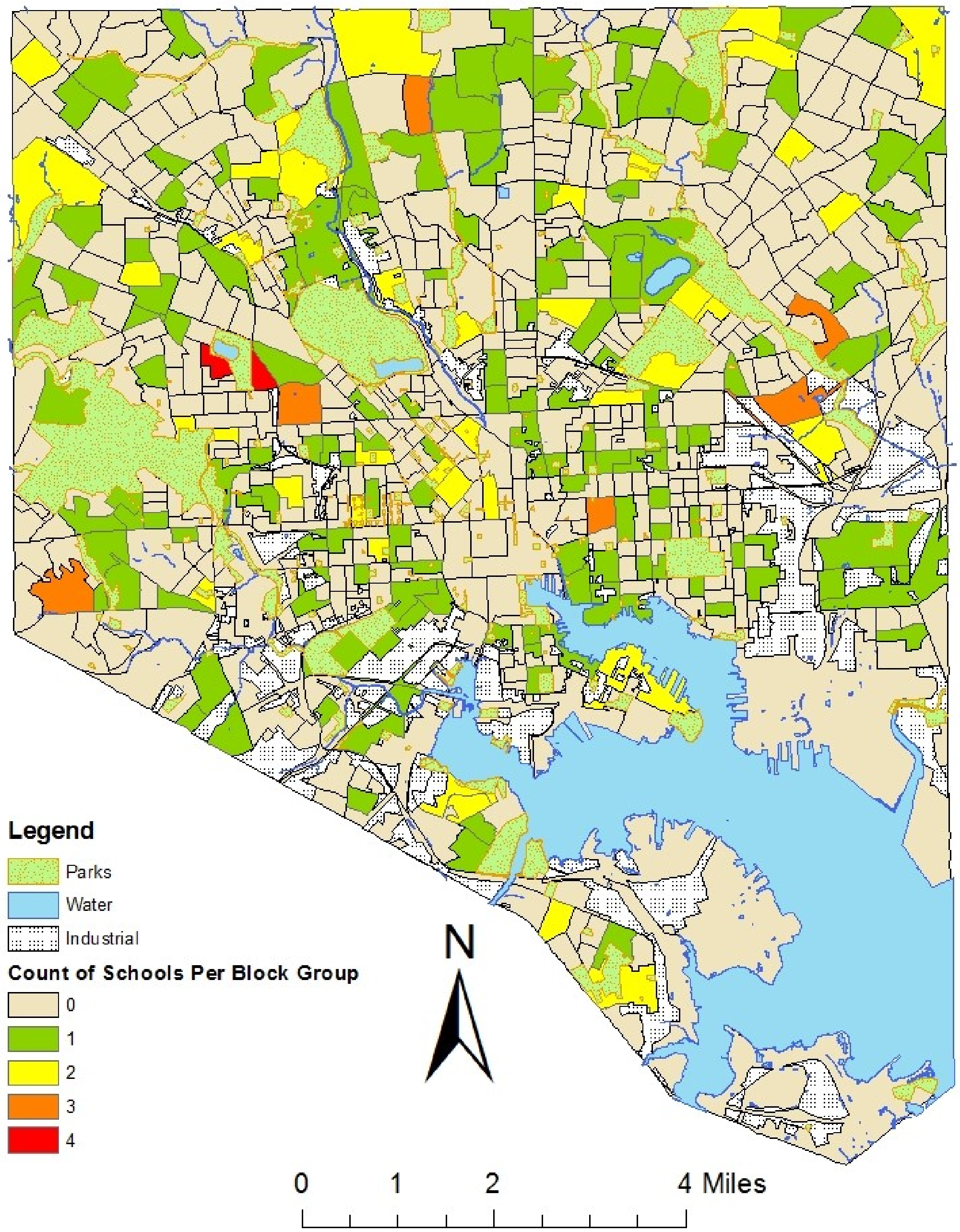
Data source: Baltimore City Housing Authority, 2015

B.7. Percent of Land Parcels that are Vacant per Block Group, Baltimore City 2015



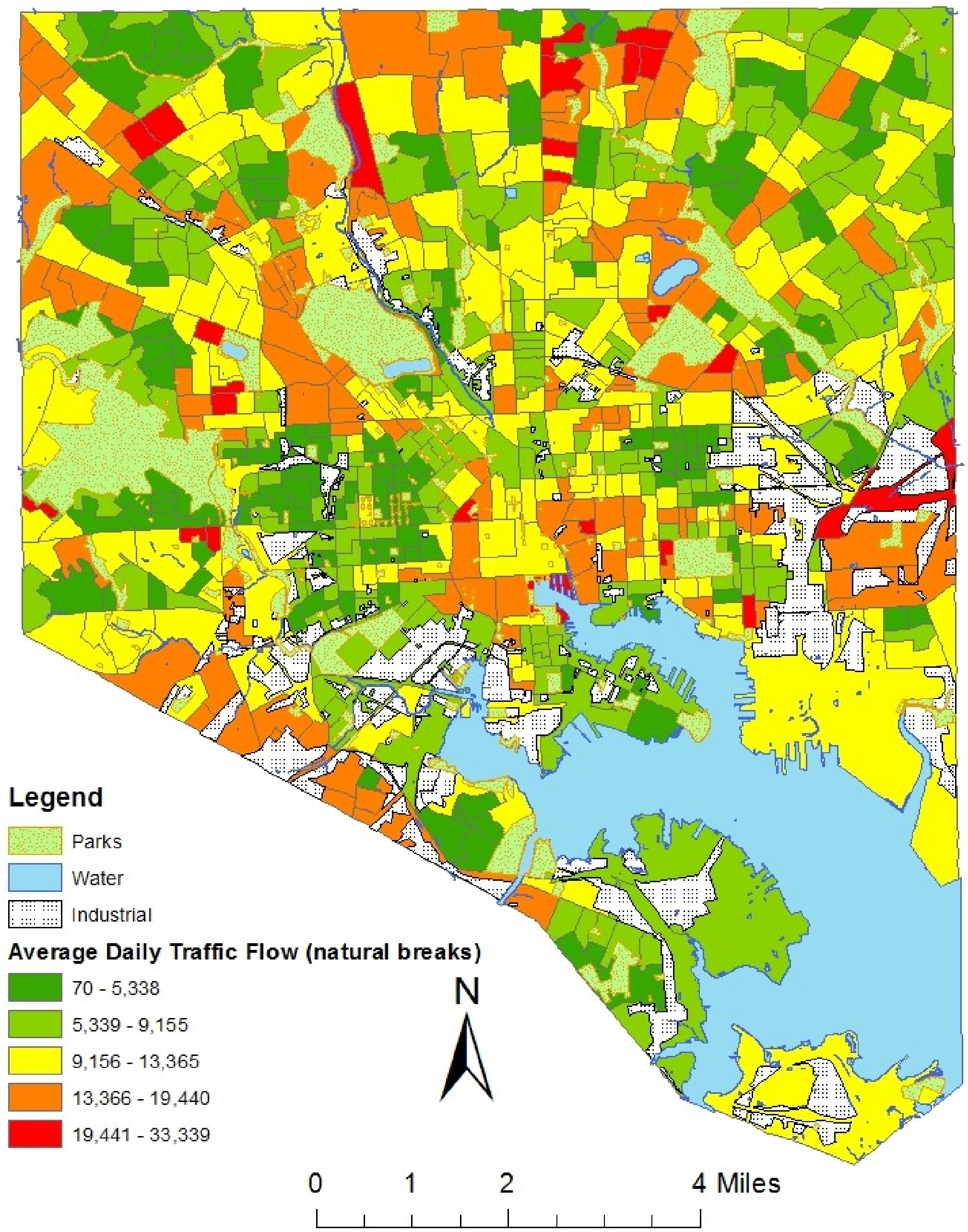
Data sources: Maryland State Department of Planning and Baltimore City Housing Authority, 2015

B.8. K-12 Public, Private, Charter, Special Ed. Schools by Block Group, Baltimore City 2015



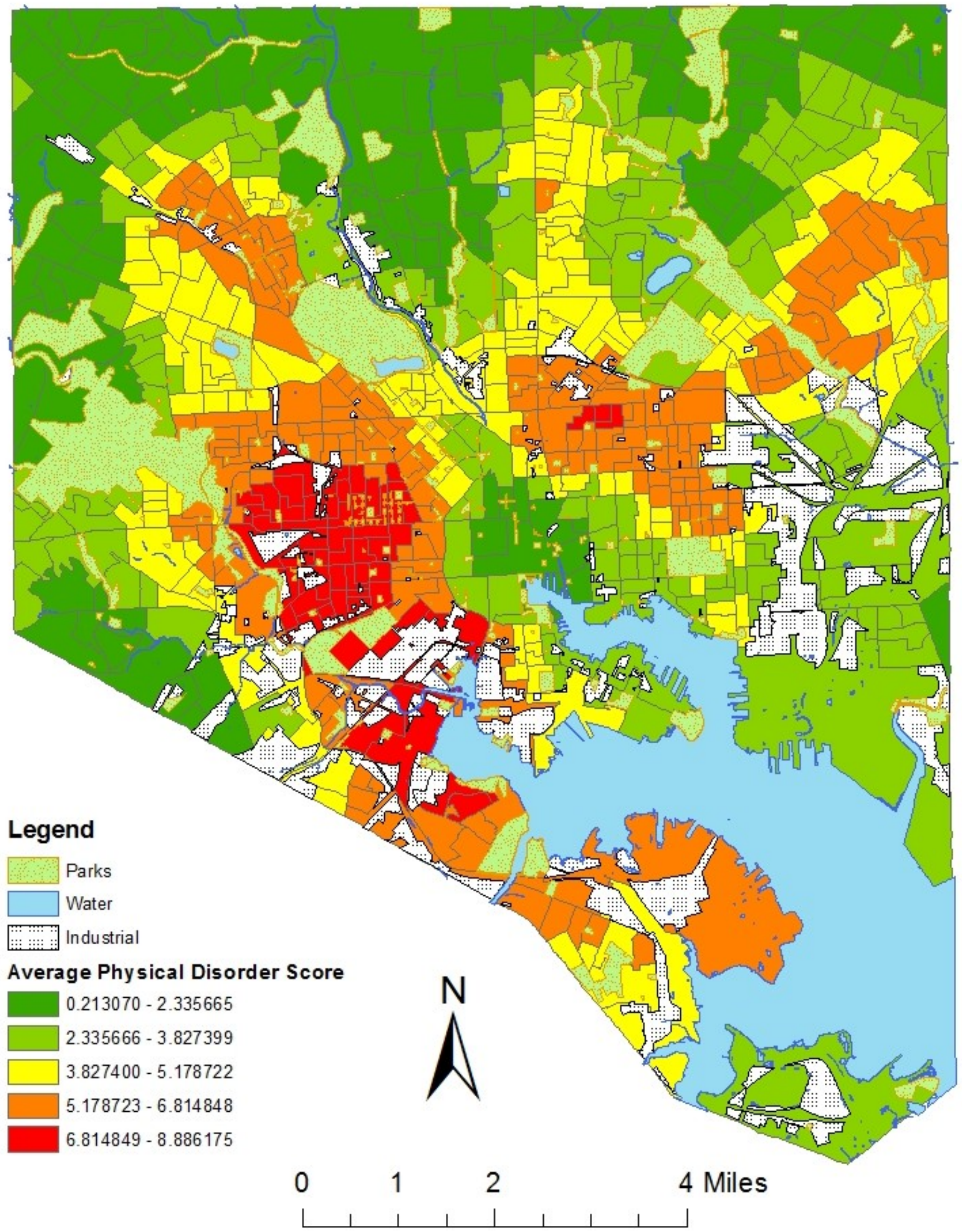
Data sources: Maryland State Department of Education and Baltimore City Public Schools, 2015

B.9. Average Daily Traffic Volume by Block Group, Baltimore City 2013



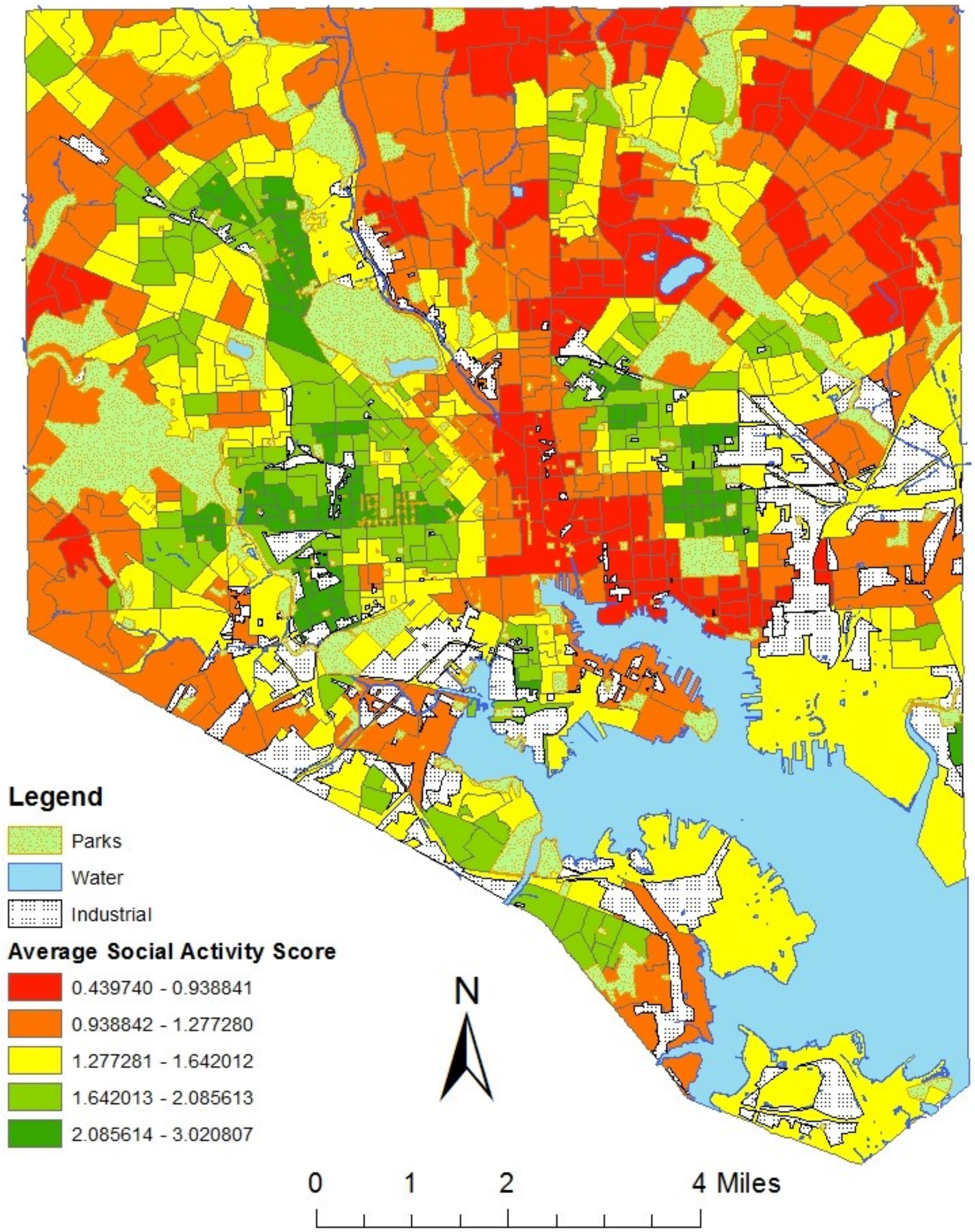
Data Source: Maryland State Highway Administration's Traffic Monitoring System, 2013

B.10. Average Physical Disorder Score by Block Group, Baltimore City 2012



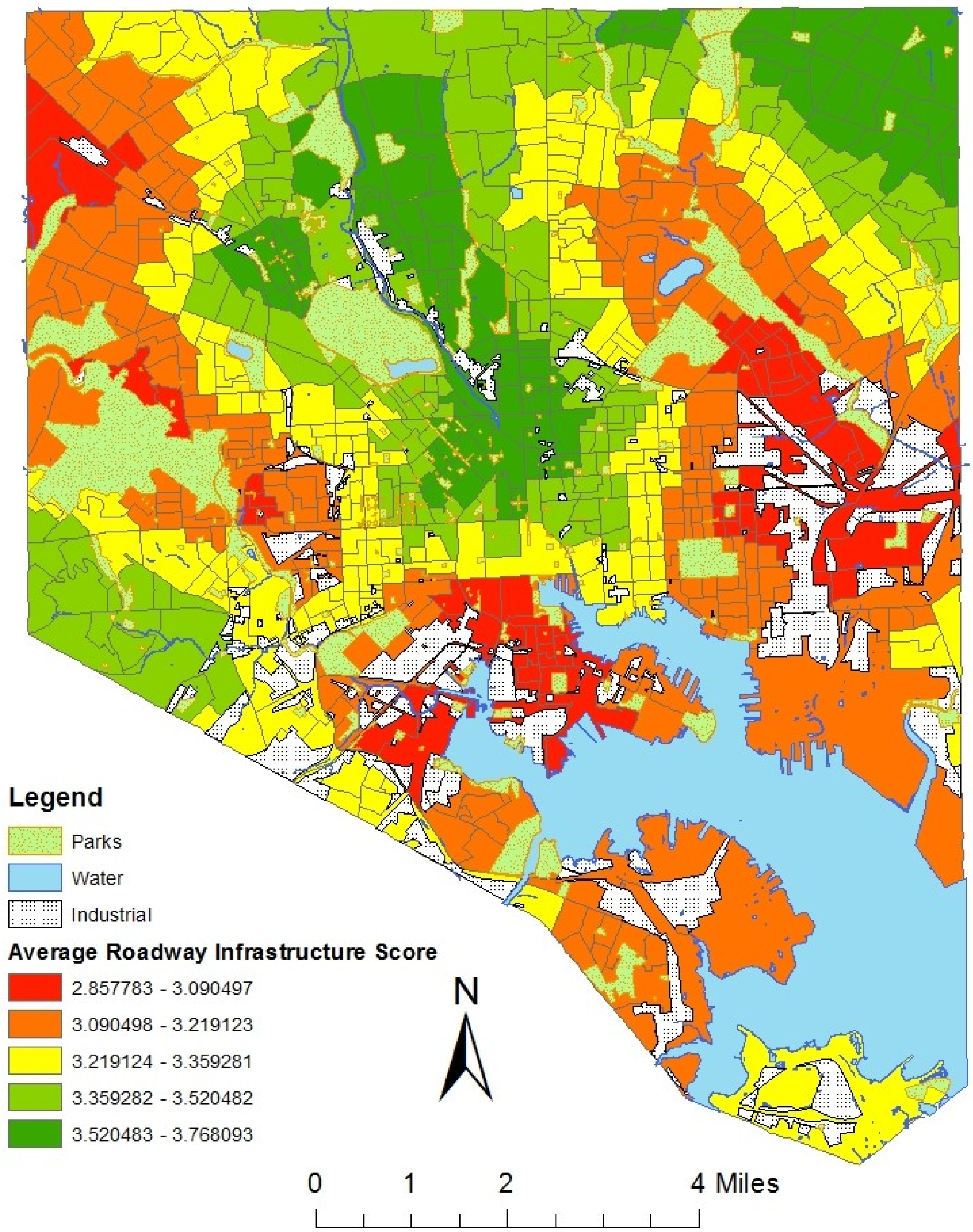
Data Source: Neighborhood Inventory for Environmental Typology Instrument, 2012

B.11. Average Social Activity Score by Block Group, Baltimore City 2012



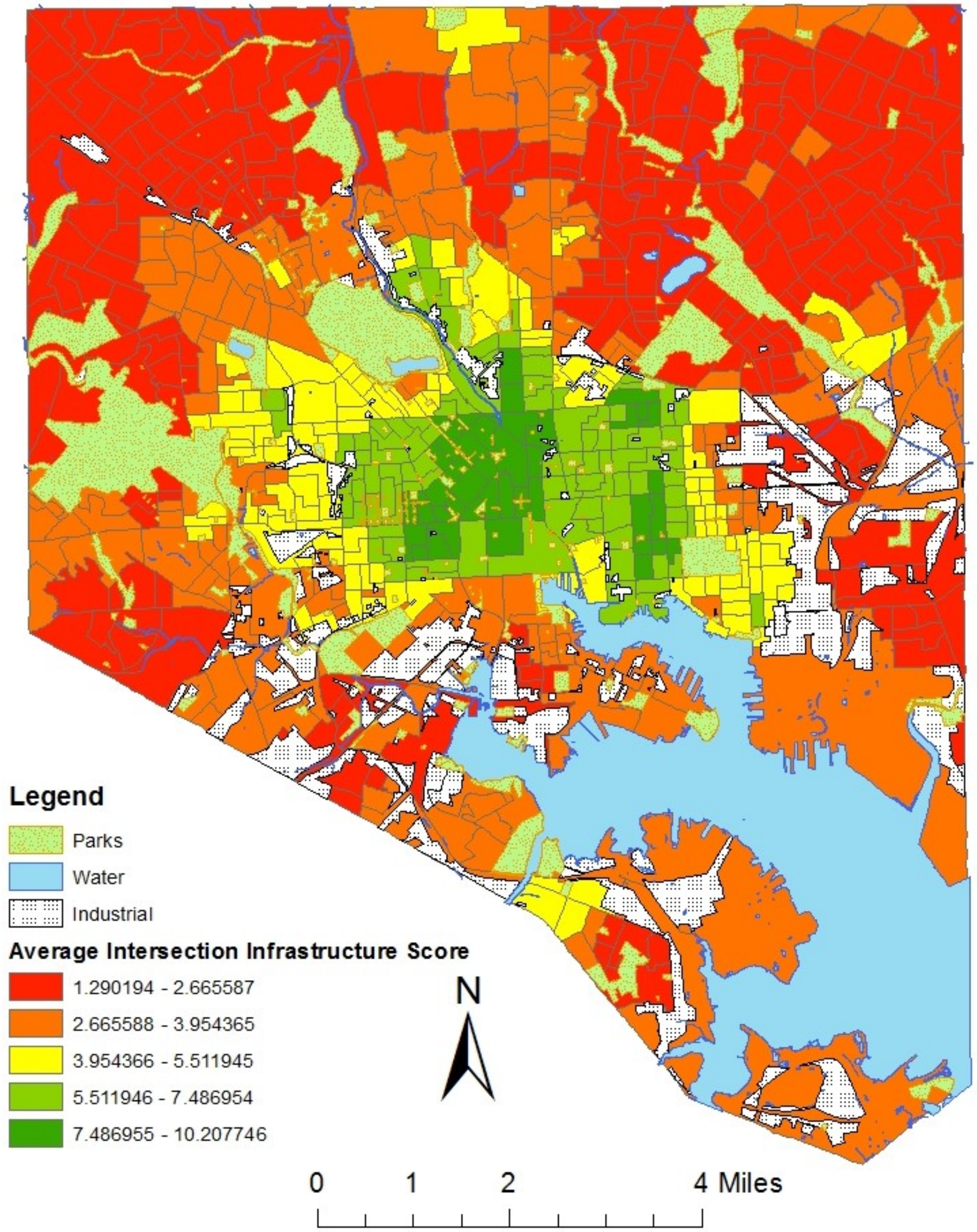
Data Source: Neighborhood Inventory for Environmental Typology Instrument, 2012

B.12. Average Roadway Infrastructure Score by Block Group, Baltimore City 2014



Data Source: Inventory for Pedestrian Safety Infrastructure, 2014

B.13. Average Intersection Infrastructure Score by Block Group, Baltimore City 2014



Data Source: Inventory for Pedestrian Safety Infrastructure, 2014

APPENDIX C. PRELIMINARY MODELING—EXPLORATORY SPATIAL DATA ANALYSIS

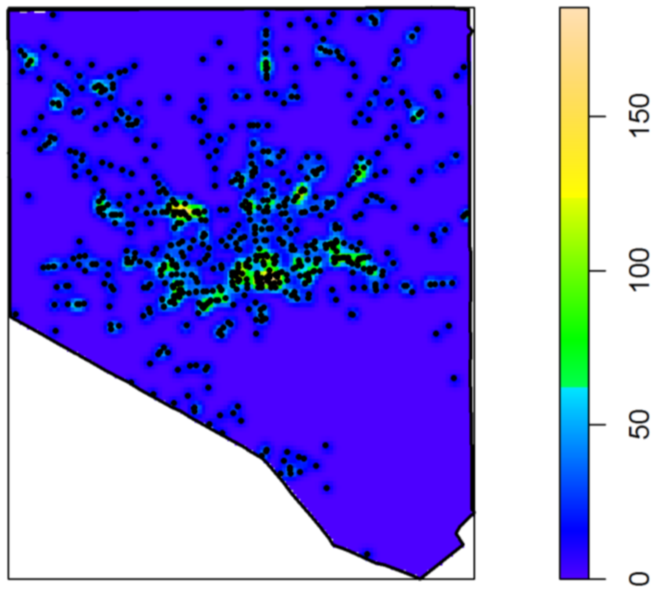
Geocoded locations of pedestrian injuries and alcohol outlets were mapped in ArcGIS 10.4, and the spatial intensity for locations of alcohol outlets and pedestrian injuries was then assessed. Exploratory spatial analyses were performed in R 3.3. Intensity is defined as the expected number of pedestrian injuries and alcohol outlets per unit area. Figures C.1-8 display mapped kernel intensity estimates at different bandwidths. These were used to assess geographic variability among pedestrian injuries and alcohol outlets, respectively. Kernel intensity estimates indicated spatial variation in risk for pedestrian injury and alcohol outlet locations. Figure C.9 displays the spatial intensity of pedestrian injuries with the locations of alcohol outlets, indicating a possible association between locations of injuries and locations of outlets.

Correlograms of Moran's *I* for count of pedestrian injuries and count of alcohol outlets are displayed in Figures C.10 and C.11. Correlograms show the correlation of spatial observations with increasing the distance (lag) between them; they are plots of Moran's *I* (an index of spatial autocorrelation) against distance.

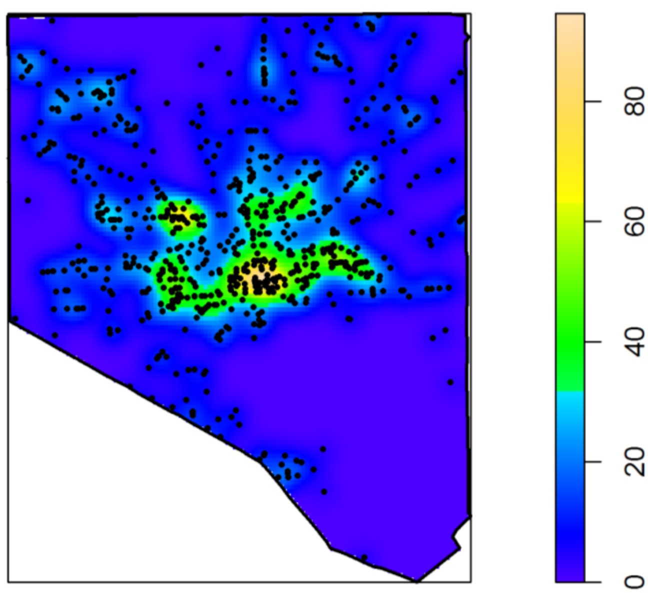
The Cross K function (Figure C.12) was calculated to assess clustering of pedestrian injuries around the fixed locations of alcohol outlets. The Cross K Function indicated that pedestrian injuries clustered around off-premise alcohol outlets more than what would be expected under a hypothesis of total independence. For example, at a radius of 0.25 miles around an alcohol outlet, under total independence, we would expect to observe approximately 11 pedestrian injuries; we observe approximately 25 injuries.

Figures C.1-4. Maps of Spatial Intensity of Pedestrian Injuries at Varying Bandwidths

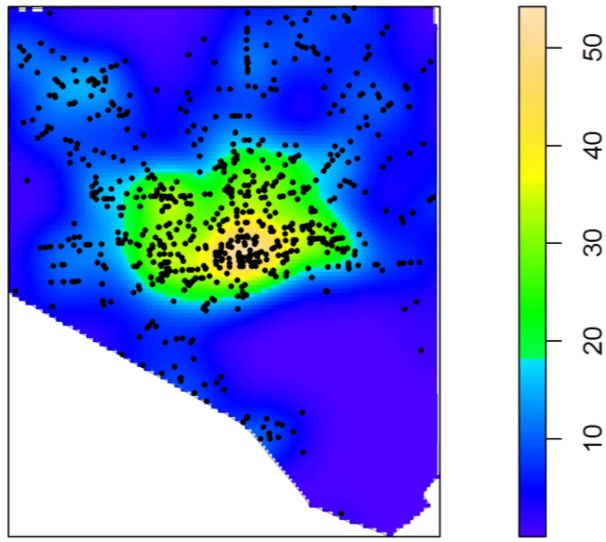
1. Bandwidth: 0.1 miles



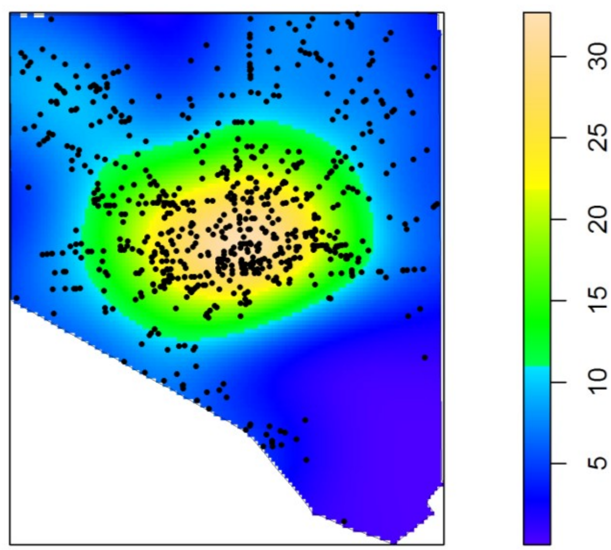
2. Bandwidth: 0.25 miles



3. Bandwidth: 0.5 miles



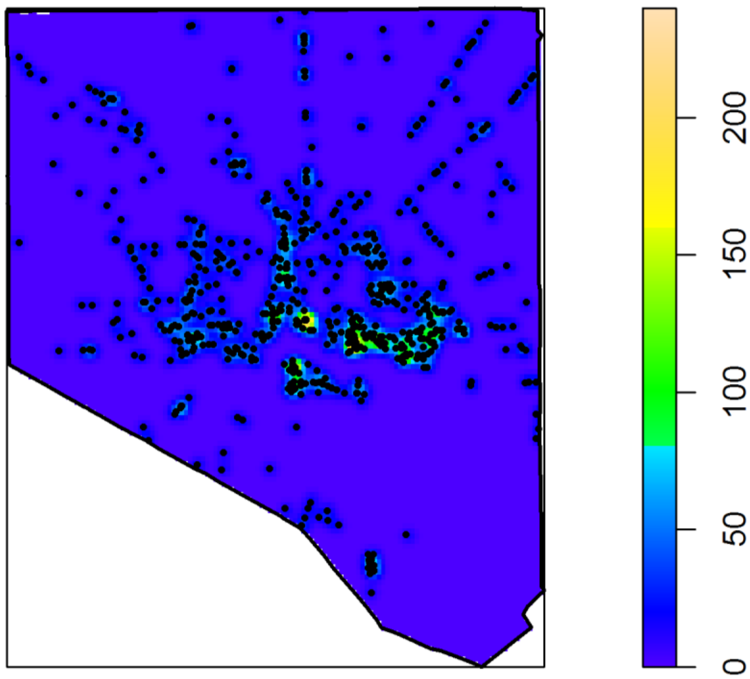
4. Bandwidth: 1.00 miles



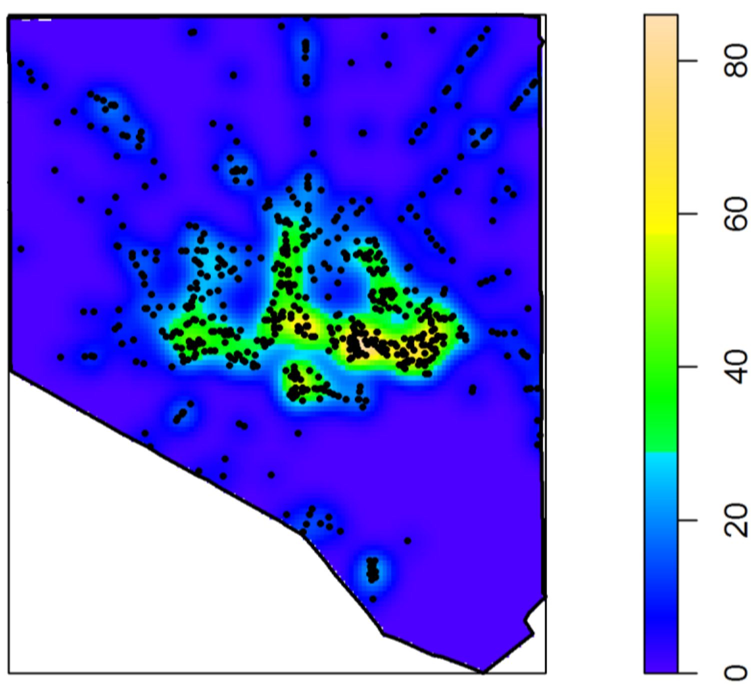
Data source: Baltimore City Fire Department Emergency Medical Services, 2014-15

Figures C. 5-8. Maps of Spatial Intensity of Alcohol Outlets at Varying Bandwidths

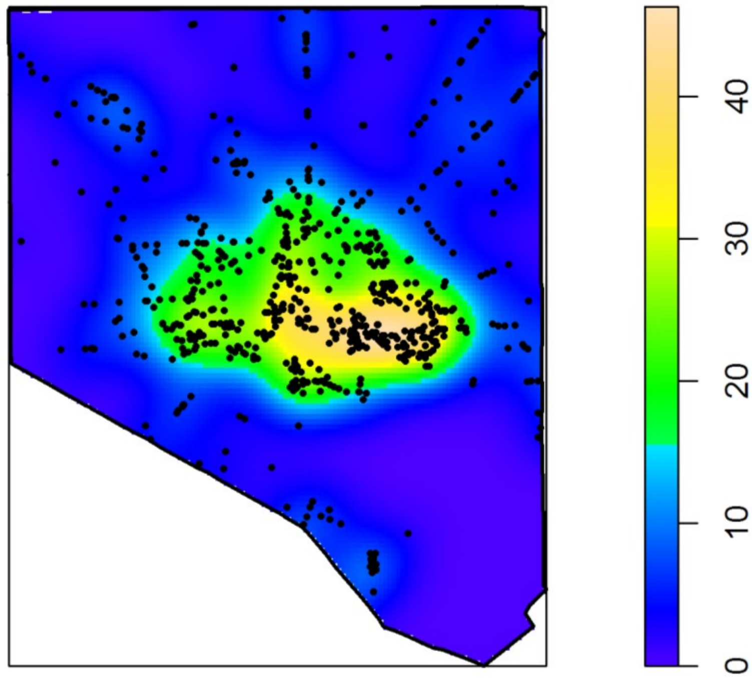
5. Bandwidth: 0.1 miles



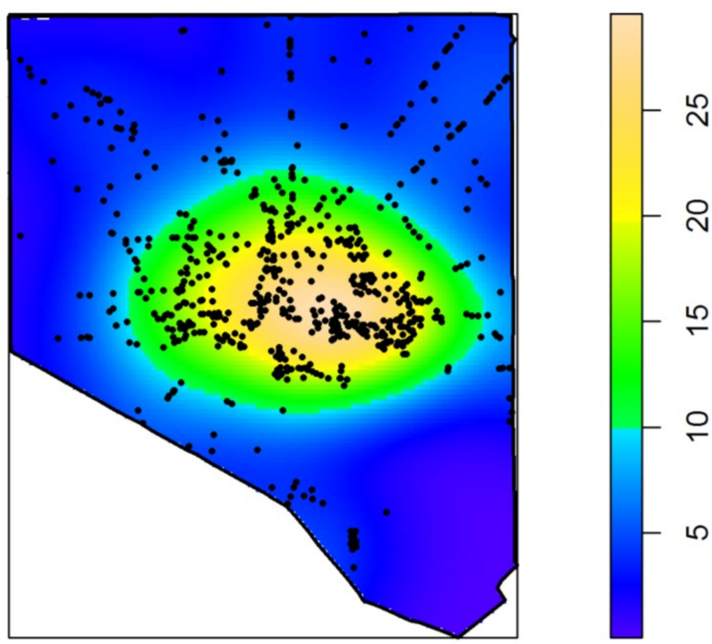
6. Bandwidth: 0.25 miles



7. Bandwidth: 0.5 miles



8. Bandwidth: 1.00 miles



Data source: Board of Liquor License Commissioners for Baltimore City, 2014

Figure C.9. Spatial Intensity of Pedestrian Injuries with Alcohol Outlet Locations

Bandwidth: 0.25 miles

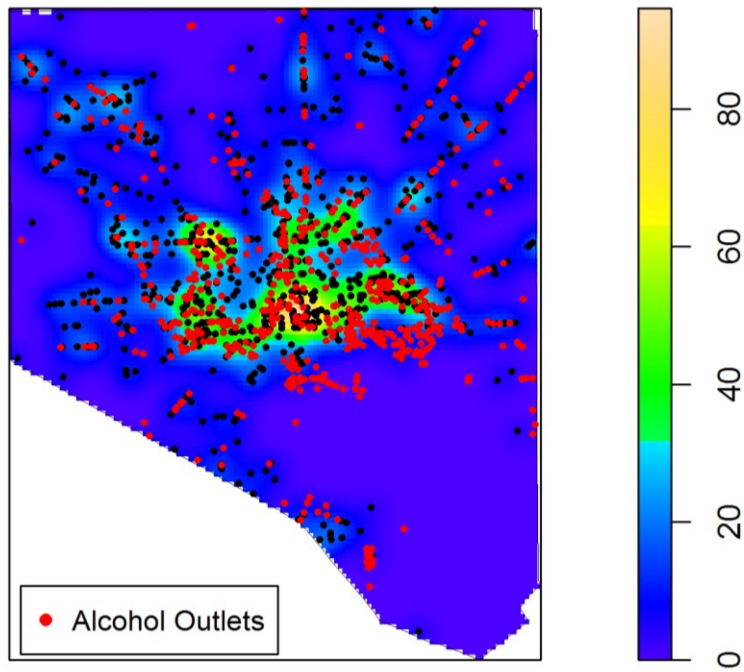


Figure C.10. Correlogram of Moran's *I* for Pedestrian Injury Count

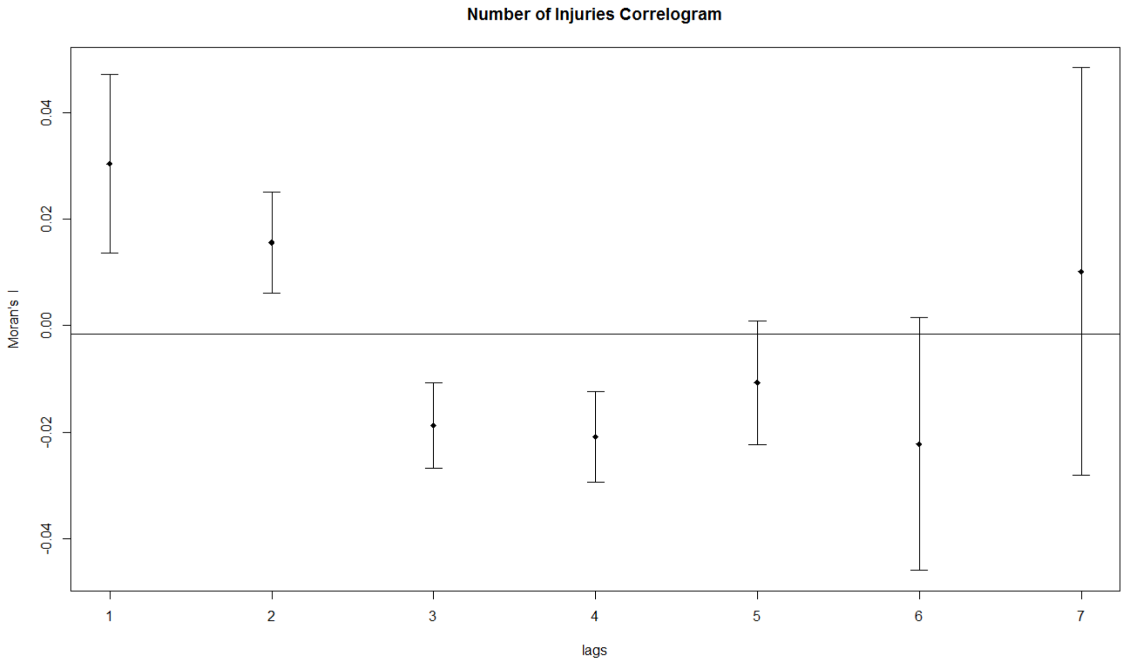


Figure C.11. Correlogram of Moran's *I* for Alcohol Outlet Count

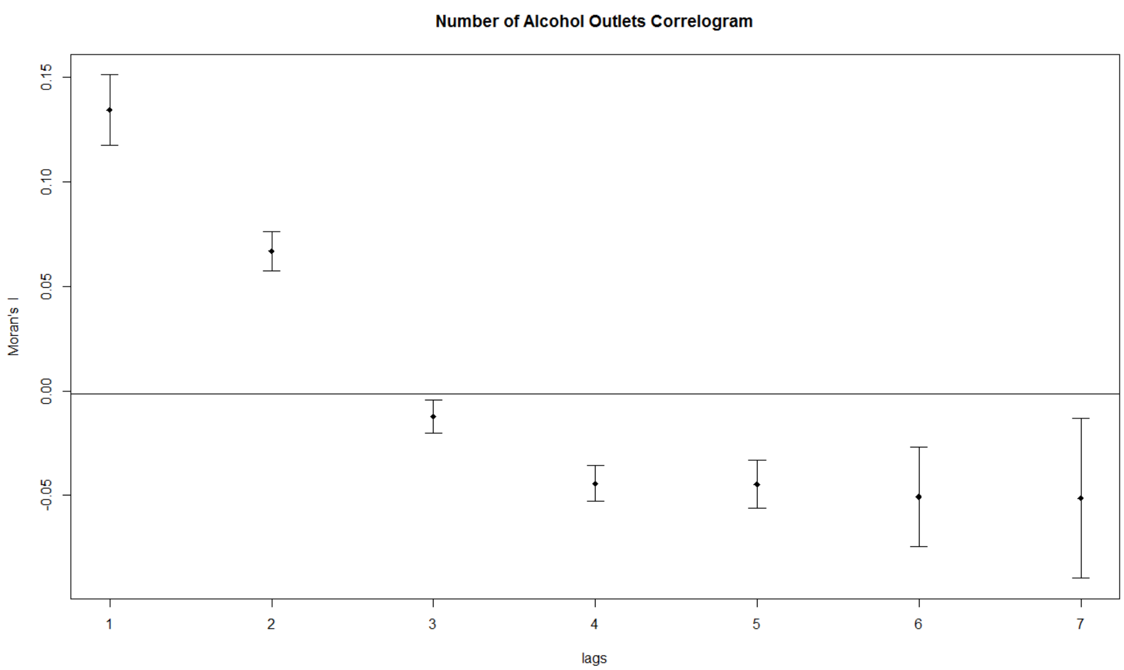
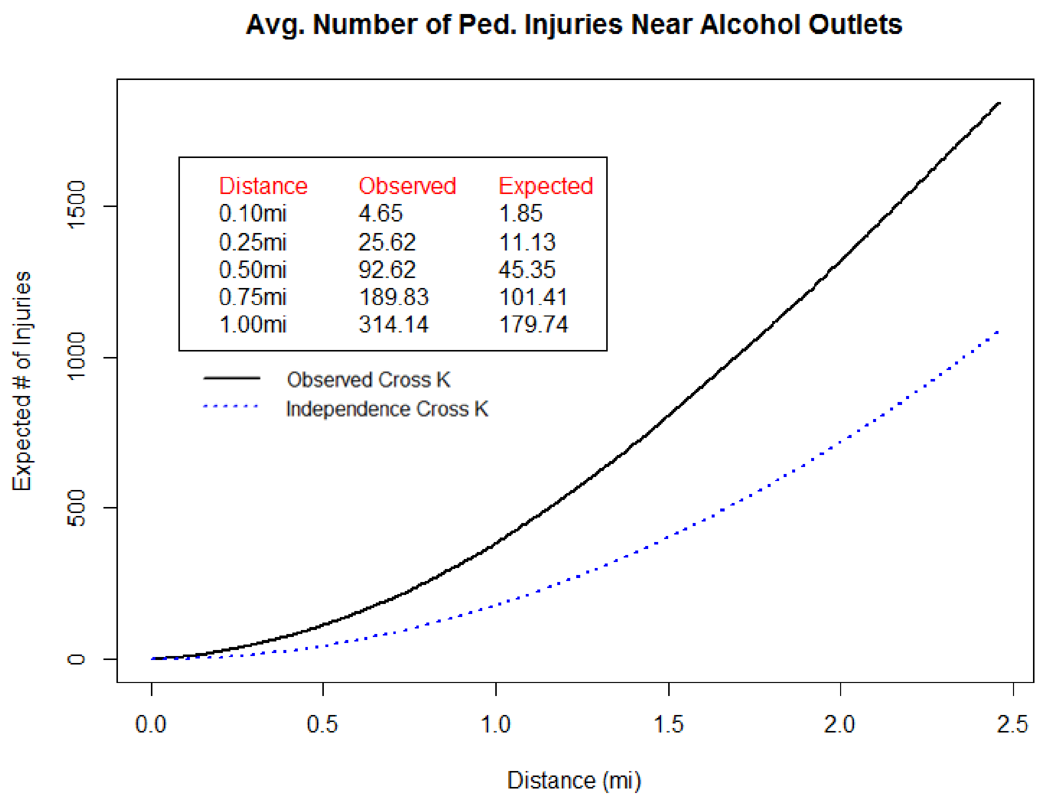


Figure C.12. Cross-K Function for Baltimore City Pedestrian Injuries & Alcohol Outlets

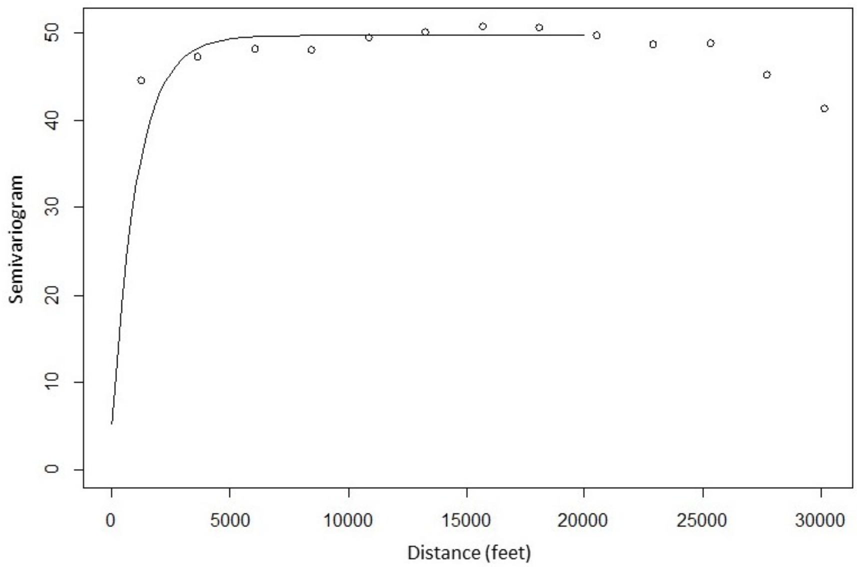


APPENDIX D. PRELIMINARY MODELING—ORDINARY KRIGING FOR SELECTED VARIABLES

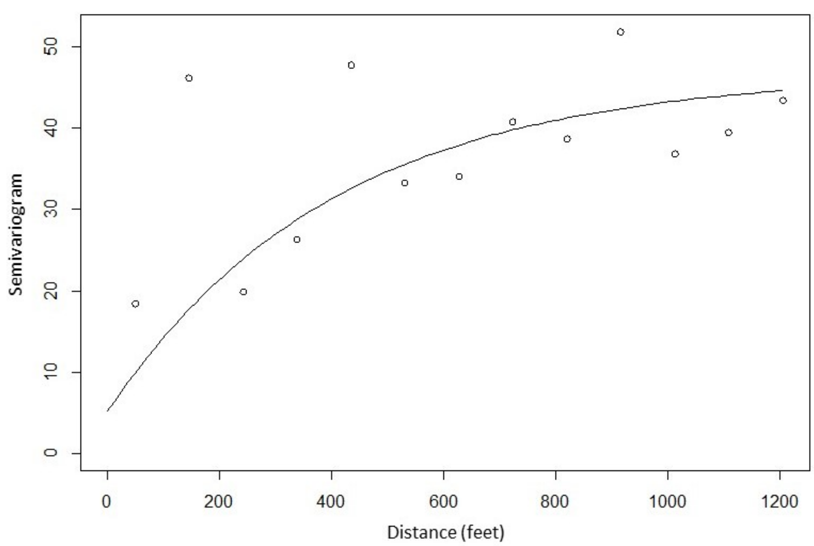
We aggregated the physical disorder, social activity, roadway and intersection infrastructure scales to the block group level. Because of the small size of block groups and the financial and temporal limitations of street sampling, 123 (18.8%) block groups lacked measures. To estimate the values for the missing block groups, we performed ordinary kriging in R 3.3 to estimate a city-wide map of values for each of the four scales. This appendix shows the results of the ordinary kriging process for each of the four scales.

Figures D.1-3. Ordinary Kriging Results for Intersection Infrastructure Score

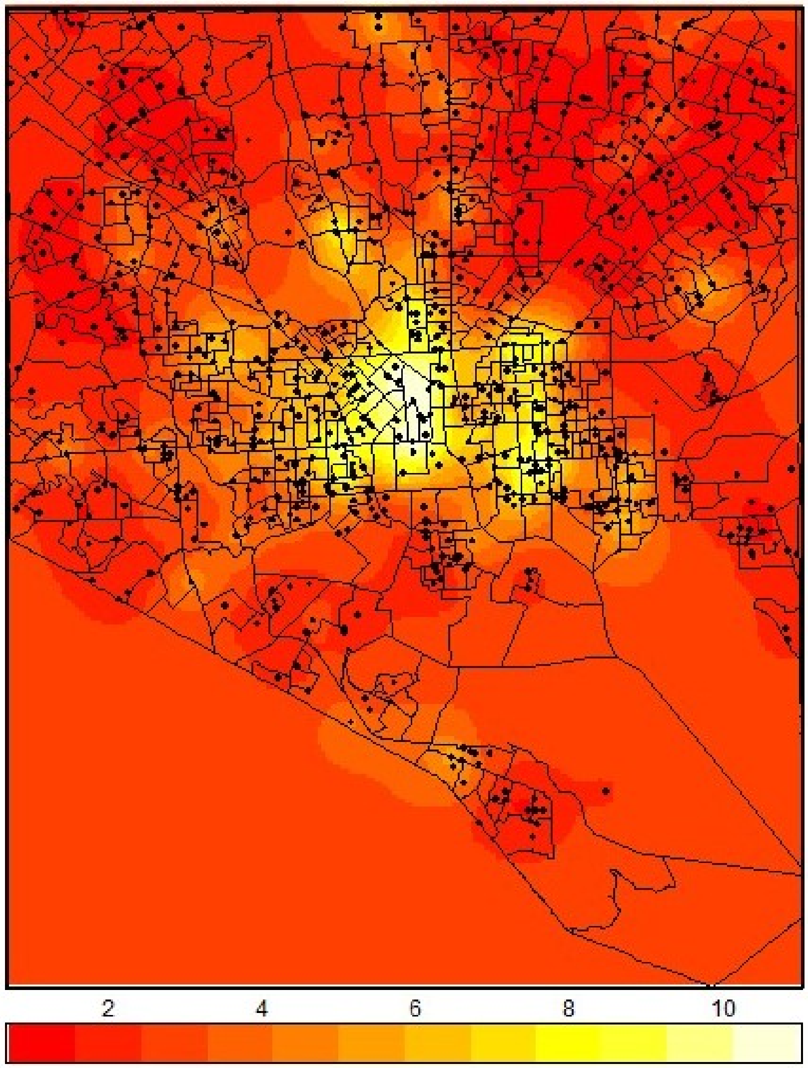
1. Intersection Score Semivariogram



2. Intersection Score Residual Semivariogram



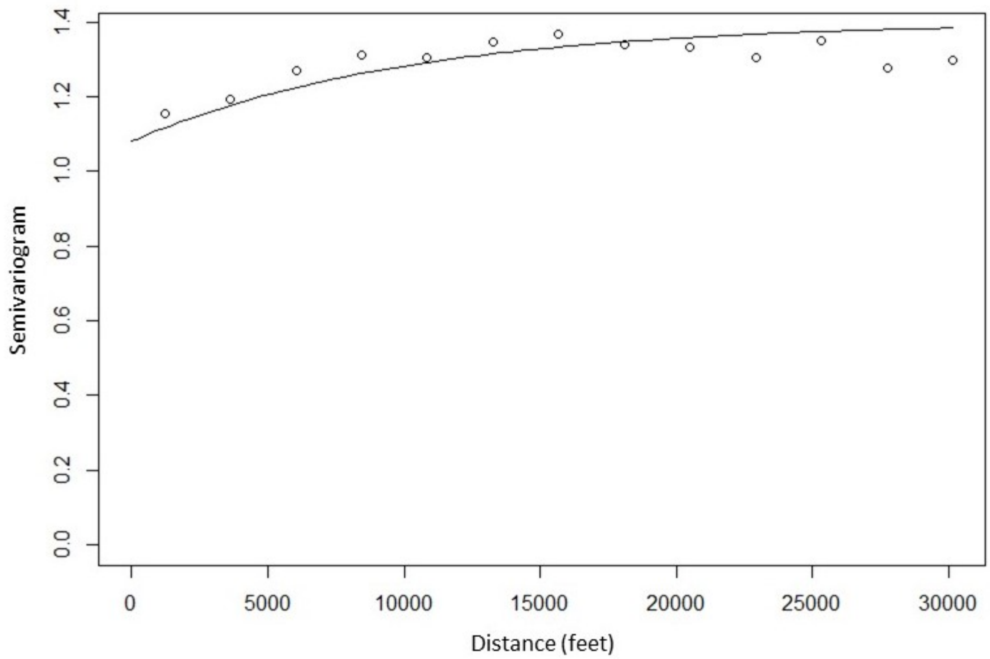
3. Ordinary Kriged Predictions of Intersection Score



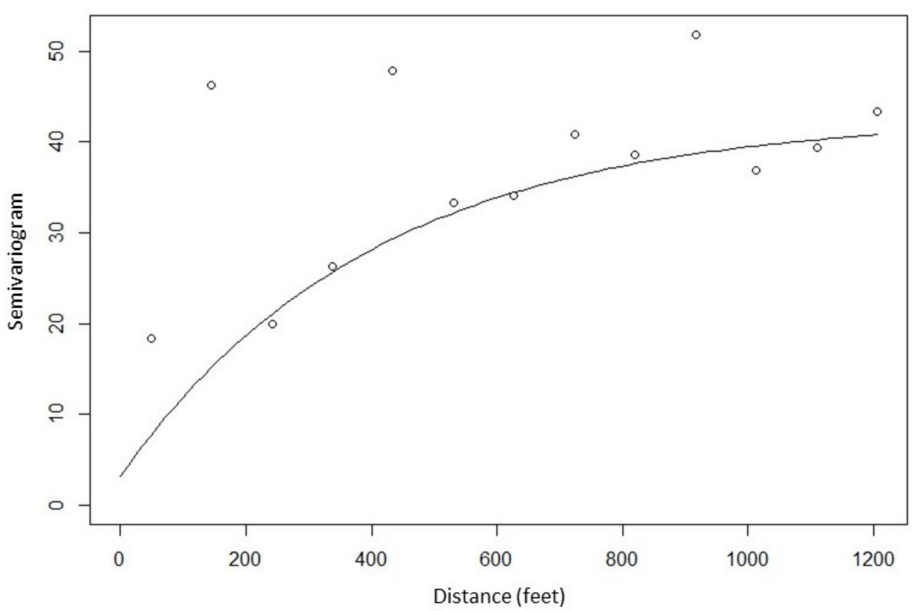
Data Source: Inventory for Pedestrian Safety Infrastructure

Figures D.4-6. Ordinary Kriging Results for Roadway Infrastructure Score

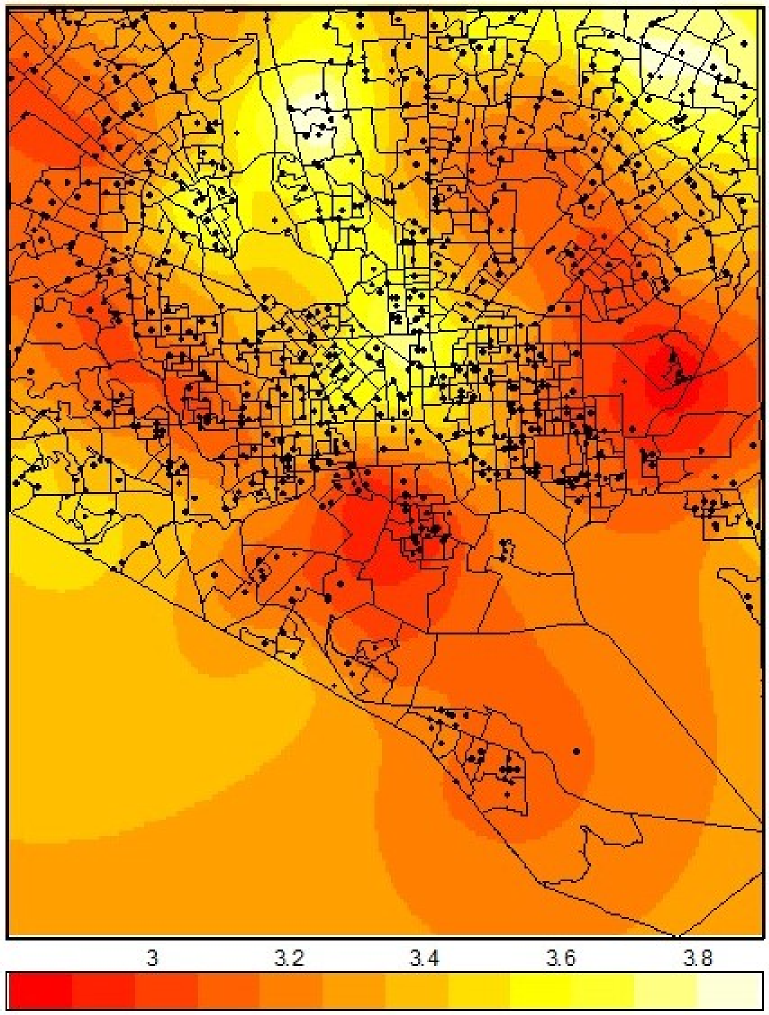
4. Roadway Infrastructure Score Semivariogram



5. Roadway Infrastructure Score Residual Semivariogram



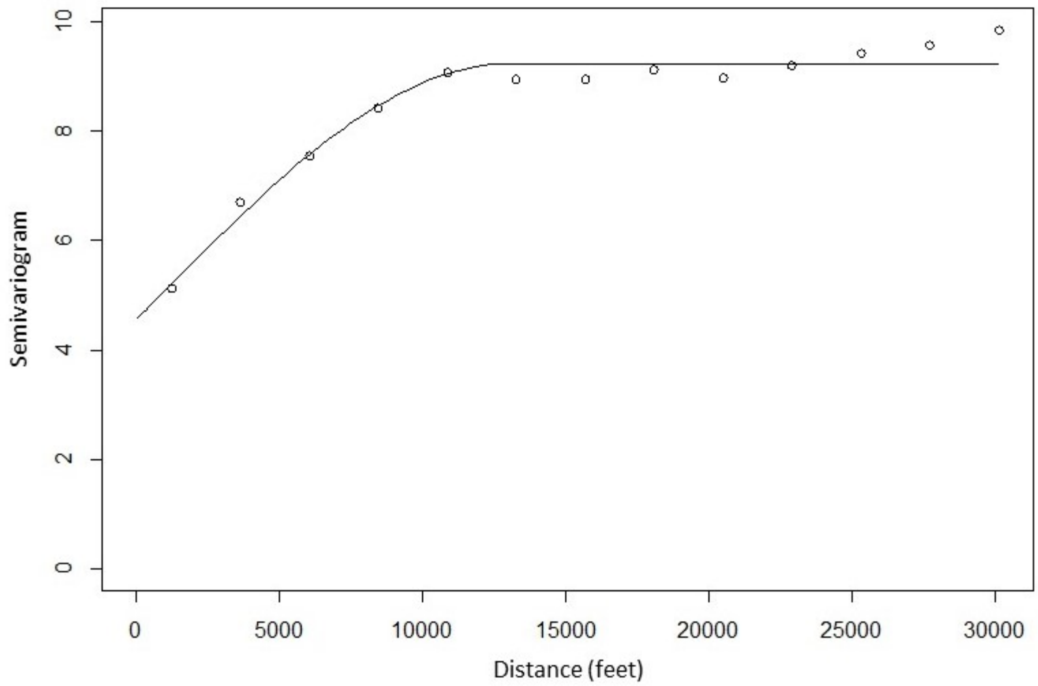
6. Ordinary Kriged Predictions of Roadway Infrastructure Score



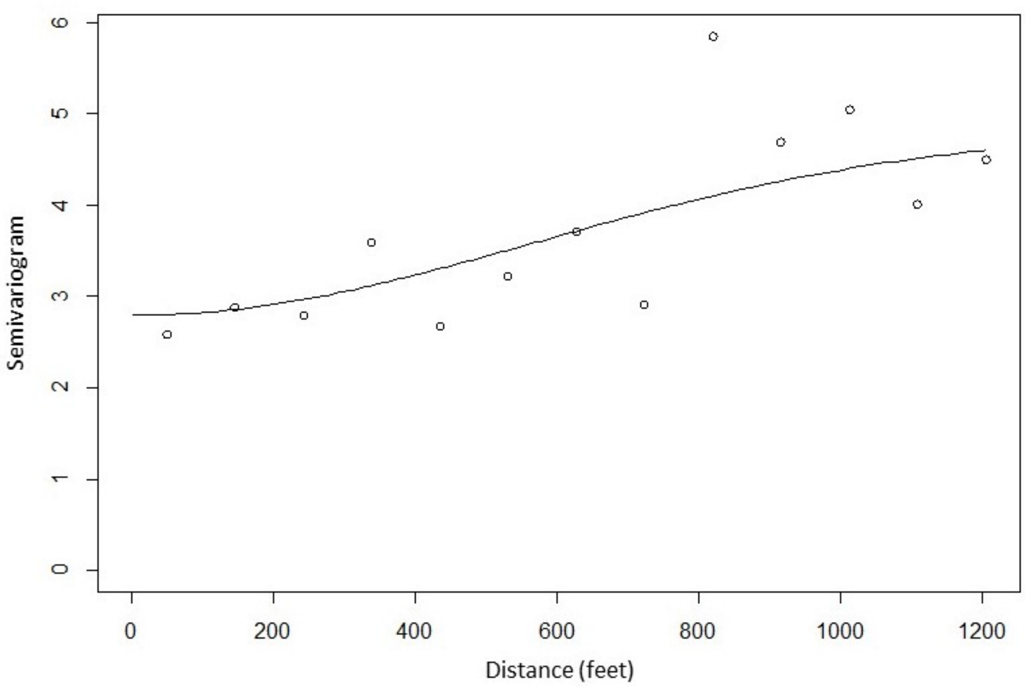
Data Source: Inventory for Pedestrian Safety Infrastructure

Figures D.7-9. Ordinary Kriging Results for Physical Disorder Score

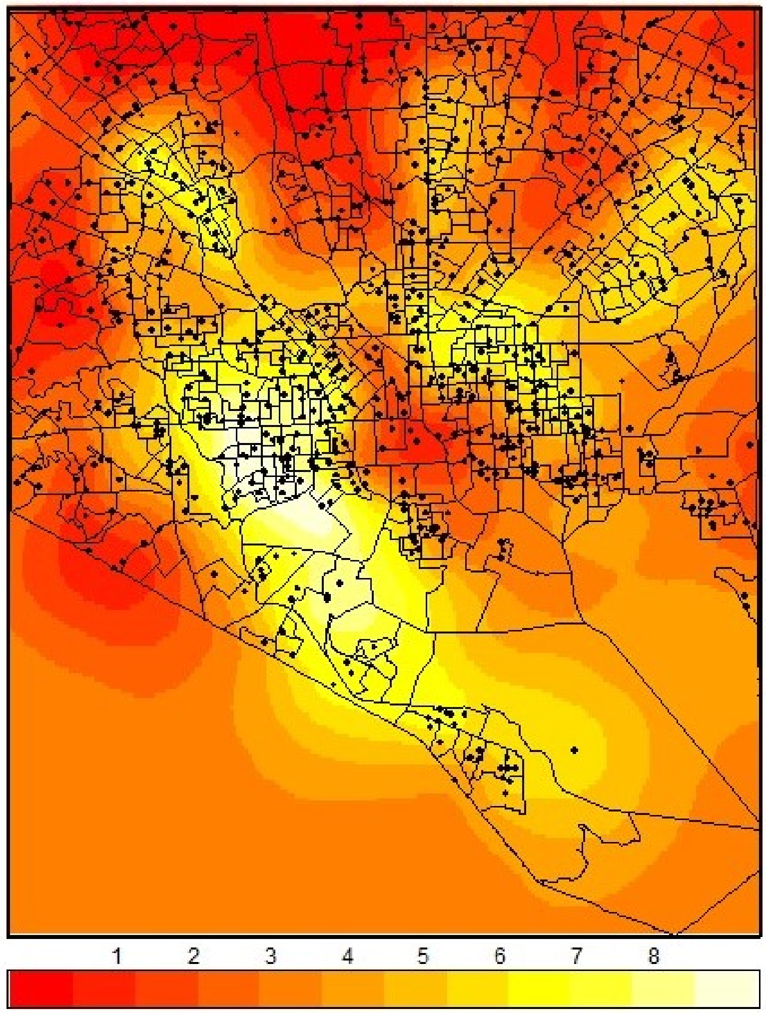
7. Physical Disorder Score Semivariogram



8. Physical Disorder Score Residual Semivariogram



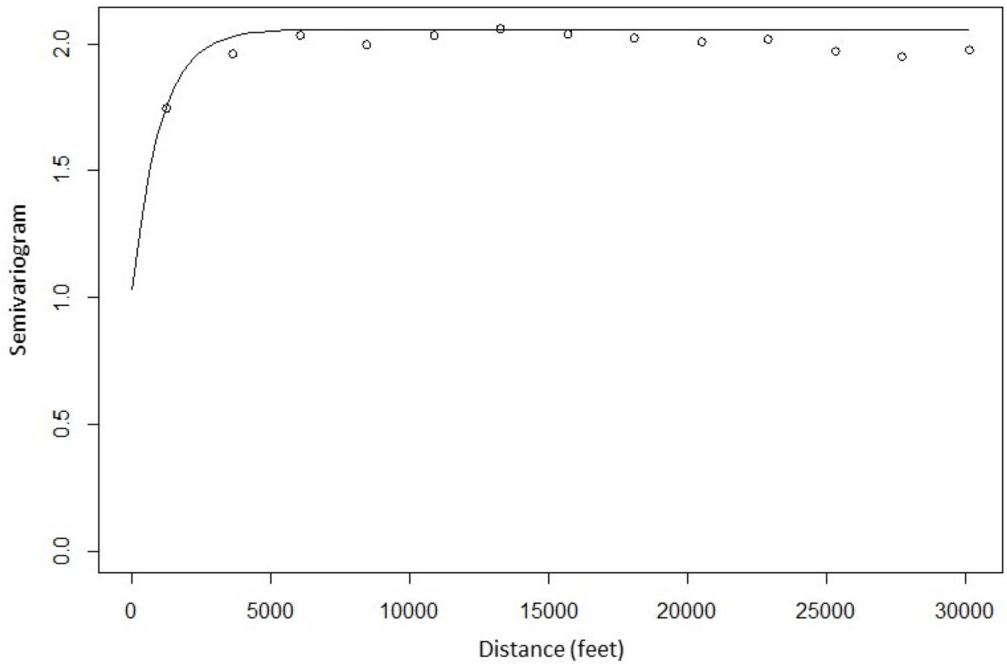
9. Ordinary Kriged Predictions of Physical Disorder Score



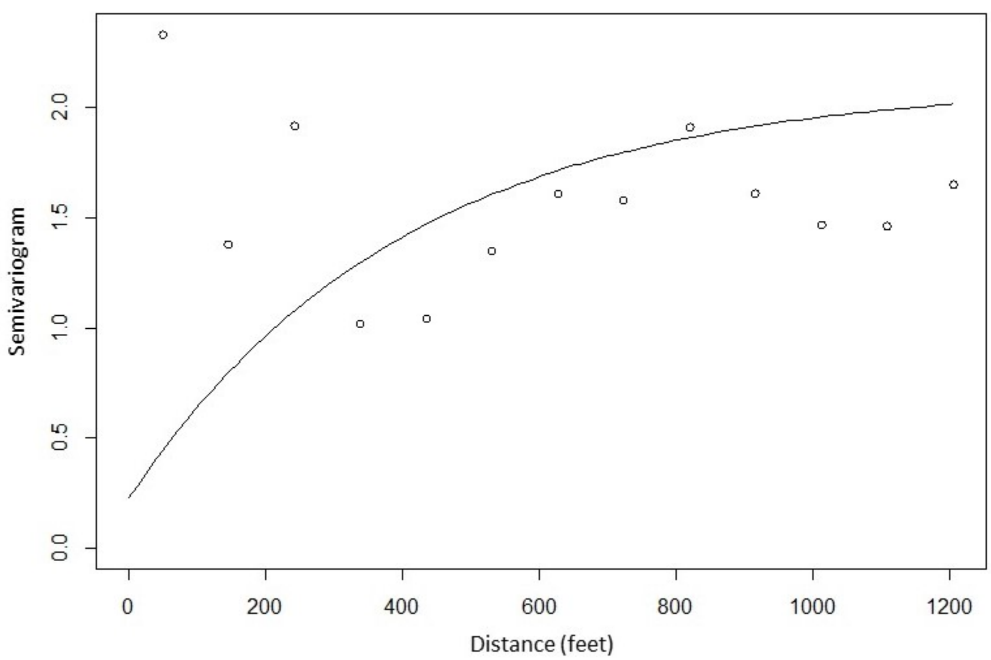
Data Source: Neighborhood Inventory for Environmental Typology

Figures D.10-12. Ordinary Kriging Results for Social Activity Score

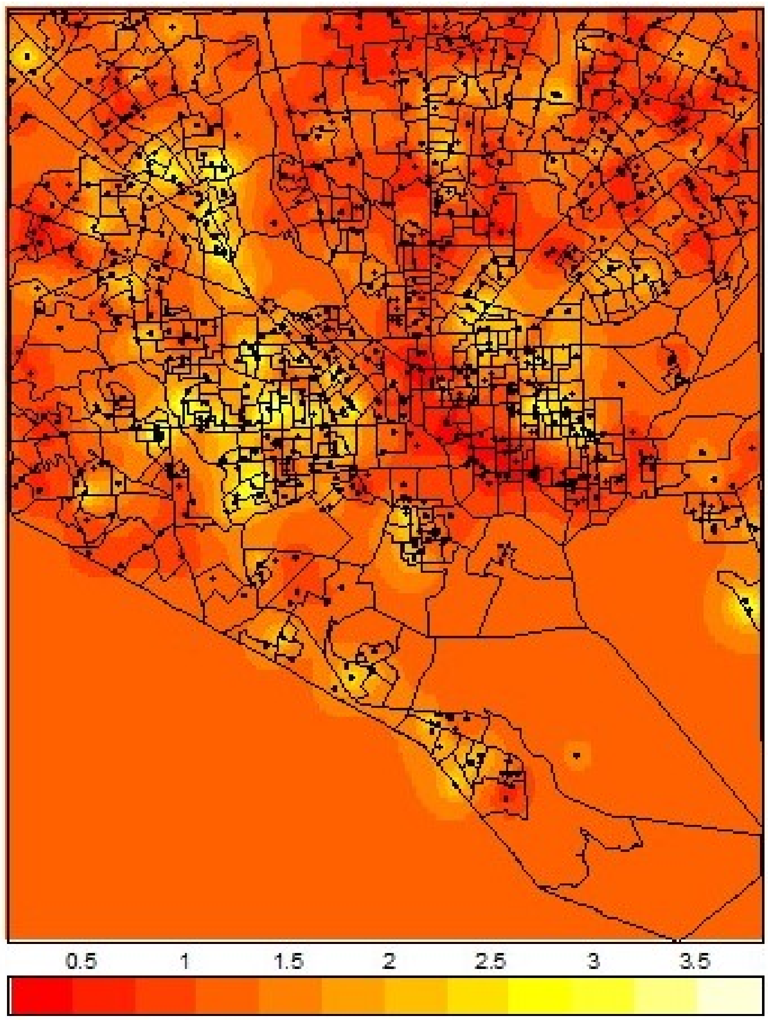
10. Social Activity Score Semivariogram



11. Social Activity Score Residual Semivariogram



12. Ordinary Kriged Predictions of Social Activity Score



Data Source: Neighborhood Inventory for Environmental Typology

APPENDIX E. SUMMARY OF STEPWISE SPATIAL MODELING

Table E.1. Description of selected characteristics by census block group (n=653)

Variable by Block Group	N	Min.	Max.	Mean	SD
Pedestrian Injuries	848	0	40	1.30	2.36
Alcohol Outlet count	693	0	32	1.06	2.13
Percent of all lots that are vacant (%)	--	0	49.53	7.02	9.65
Median Household income (in $1,000s)	--	0	224.43	44.81	27.72
Mean daily traffic volume (in 1,000 vehicles)	--	0.07	33.34	9.71	5.13
K-12 Schools (public, private, special education)	239	0	4	0.37	0.65
Total population (per 1,000 residents)	622.27	0	4.83	0.95	0.52
Population density (per square mile in 1,000 residents)	--	0	95.16	13.72	9.94
Distance from downtown (miles)	--	0	7.5	3.32	1.59
Physical disorder (range: 0-12)	--	0.21	8.89	4.30	1.92
Social activity (range: 0-6)	--	0.44	3.02	1.43	0.50
Roadway infrastructure (range: 0-8)	--	2.86	3.77	3.30	0.18
Intersection infrastructure (range: 0-21)	--	1.29	10.21	3.84	1.96

SECTION I. POISSON REGRESSION MODELS

Poisson regression was performed in R 3.3, analyzing the counts of pedestrian injuries per block group, while adding each control variable in a stepwise fashion. As each control variable was added, over-dispersion statistics and Residual Moran's *I* were calculated to assess residual spatial variation not accounted for by the model's covariates. Akaike's Information Criterion was also calculated for each model to select the best fitting and most parsimonious model.

Table E.2. Exponentiated betas for Poisson univariate analysis by census block group

Variable	β	Univariate (RR)	p-value
Alcohol outlet count	0.119	1.13	<0.001
Population (per 1,000 residents)	0.148	1.159	0.0158
Population density (per square mile in 1,000 residents)	-0.0156	0.984	<0.001
Percent of all lots that are vacant (%)	0.018	1.018	<0.001
Median household income (in $1,000s)	-0.008	0.99	<0.001
Mean daily traffic volume (in 1,000 vehicles)	0.0319	1.032	<0.001
Schools	0.0989	1.104	0.0488
Physical disorder	0.045	1.046	0.0117
Social activity	-0.0157	0.984	0.822
Roadway infrastructure	-0.113	0.893	0.554
Intersection infrastructure	0.153	1.165	<0.001
Distance from downtown	-0.272	0.762	<0.001

Table E.3. Exponentiated betas and fit statistics, including over-dispersion statistics and Residual Moran's *I*, for Poisson multivariate analysis by census block group

	Variables	β_1 RR (p)	β_2 RR (p)	β_3 RR (p)	β_4 RR (p)	β_5 RR (p)	β_6 RR (p)	β_7 RR (p)	β_8 RR (p)	X^2	N-p	$\sqrt{(X^2/N\text{-}p)}$	Residual Moran's *I* (p)	AIC
Null	Injury count												0.215 (<0.001)	
1	1. Alcohol	1.130 (<0.001)								1489	651	1.51	0.138 (<0.001)	2212
2	1. Alcohol 2. Population	1.128 (<0.001)	0.952 (0.484)							1486	650	1.51	0.138 (<0.001)	2213
3	1. Alcohol 2. AreaPop	1.124 (<0.001)	0.990 (0.013)							1469	650	1.50	0.144 (<0.001)	2207
4	1. Alcohol 2. AreaPop 3. Vacant%	1.128 (<0.001)	0.987 (0.001)	1.023 (<0.001)						1428	649	1.48	0.131 (<0.001)	2161
5	1. Alcohol 2. AreaPop 3. Vacant% 4. Income	1.135 (<0.001)	0.988 (0.002)	1.015 (<0.001)	0.990 (<0.001)					1388	648	1.46	0.108 (<0.001)	2127
6	1. Alcohol 2. AreaPop 3. Vacant% 4. Income 5. Traffic	1.132 (<0.001)	0.988 (0.004)	1.018 (<0.001)	0.991 (<0.001)	1.034 (<0.001)				1356	647	1.45	0.081 (<0.001)	2106
7	1. Alcohol 2. AreaPop 3. Vacant% 4. Income 5. Traffic 6. Schools	1.134 (<0.001)	0.990 (0.015)	1.020 (<0.001)	0.991 (<0.001)	1.035 (<0.001)	1.146 (0.007)			1355	646	1.45	0.076 (<0.001)	2102

Table E.3. Poisson regression modeling (cont.)

	Variables	β_1 RR (p)	β_2 RR (p)	β_3 RR (p)	β_4 RR (p)	β_5 RR (p)	β_6 RR (p)	β_7 RR (p)	β_8 RR (p)	X^2	N-p	$\sqrt{(X^2/N\text{-}p)}$	Residual Moran's *I* (p)	AIC
8†	1. Alcohol 2. AreaPop 3. Vacant% 4. Income 5. Traffic 6. Schools 7. Physical Disorder	1.135 (<0.001)	0.989 (0.011)	1.016 (<0.001)	0.991 (<0.001)	1.036 (<0.001)	1.144 (0.008)	1.022 (0.402)		1357	645	1.45	0.076 (<0.001)	2103
9	1. Alcohol 2. AreaPop 3. Income 4. Traffic 5. Schools 6. Physical Disorder	1.138 (<0.001)	0.989 (0.009)	0.990 (<0.001)	1.035 (<0.001)	1.130 (0.017)	1.081 (<0.001)			1378	646	1.46	0.074 (<0.001)	2114
10	1. Alcohol 2. AreaPop 3. Vacant% 4. Income 5. Traffic 6. Schools 7. Social	1.133 (<0.001)	0.991 (0.022)	1.021 (<0.001)	0.991 (<0.001)	1.034 (<0.001)	1.146 (0.007)	0.914 (0.285)		1352	645	1.45	0.073 (<0.001)	2103
11	1. Alcohol 2. AreaPop 3. Vacant% 4. Income 5. Traffic 6. Schools 7. Roadway	1.134 (<0.001)	0.990 (0.015)	1.020 (<0.001)	0.991 (<0.001)	1.036 (<0.001)	1.148 (0.007)	0.859 (0.455)		1352	645	1.45	0.076 (<0.001)	2104

Table E.3. Poisson regression modeling (cont.)

	Variables	β_1 RR (p)	β_2 RR (p)	β_3 RR (p)	β_4 RR (p)	β_5 RR (p)	β_6 RR (p)	β_7 RR (p)	β_8 RR (p)	X^2	N-p	$\sqrt{(X^2/N\text{-}p)}$	Residual Moran's I	AIC
12	1. Alcohol 2. AreaPop 3. Vacant% 4. Income 5. Traffic 6. Schools 7. Intersect	1.123 (<0.001)	0.985 (<0.001)	1.015 (<0.001)	0.992 (<0.001)	1.034 (<0.001)	1.123 (0.020)	1.082 (<0.001)		1336	645	1.44	0.065 (0.001)	2087
13‡	1. Alcohol 2. AreaPop 3. Vacant% 4. Income 5. Traffic 6. Schools 7. Intersect 8. Distance	1.112 (<0.001)	0.983 (<0.001)	1.012 (0.001)	0.992 (<0.001)	1.034 (<0.001)	1.124 (0.020)	1.019 (0.465)	0.881 (<0.001)	1317	644	1.43	0.051 (0.009)	2078
14	1. Alcohol 2. AreaPop 3. Vacant% 4. Income 5. Traffic 6. Schools 7. Distance	1.112 (<0.001)	0.983 (<0.001)	1.013 (<0.001)	0.992 (<0.001)	1.033 (<0.001)	1.128 (0.019)	0.865 (<0.001)		1317	645	1.43	0.049 (0.010)	2076

†Correlation between Vacant Lots Percent and Physical Disorder Score: r=0.666, p<0.0001
‡Correlation between Intersection Score and Distance from downtown: r=-0.77, p<0.0001

SECTION IA. SPATIAL LAG EFFECT MODELS

We created new lagged variables for alcohol, AreaPop, VacantPercent, Income, Traffic, Schools, Distance. We replaced the lagged variable in each model 1-14 and assessed AIC and Residual Moran's *I* and found that Model 14 with lagged Traffic had the best fit (AIC=2056, Residual Moran's *I*=0.047, p=0.013). We then kept the Traffic value lagged and added in each an additional lagged version of each variable. We replaced the non-lagged variables with lagged variables, keeping Traffic as lagged; the AIC increased and Residual Moran's *I* did not improve.

Table E.4. Exponentiated betas and fit statistics for Poisson multivariate analysis using the spatial lag of traffic volume

		β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8					
Model	**Variables**	RR (p)	RR (p)	RR (p)	RR (p)	RR (p)	RR (p)	RR (p)	RR (p)	**X^2**	**N-p**	**$\sqrt{(X^2/N\text{-}p)}$**	**Residual Moran's *I*** (p)	**AIC**
15	1. Alcohol 2. AreaPop 3. Vacant% 4. Income 5. TrafficLag 6. Schools 7. Distance	1.106 (<0.001)	0.984 (<0.001)	1.016 (<0.001)	0.991 (<0.001)	1.086 (<0.001)	1.125 (0.020)	0.876 (<0.001)		1242	645	1.39	0.047 (0.013)	2056

SECTION II. NEGATIVE BINOMIAL REGRESSION MODELS

Because the best-fitting Poisson model was over-dispersed with significant unexplained spatial variation, model selection was repeated with the negative binomial distribution using the same stepwise system of covariate selection. Negative binomial regression derives as an alternative to Poisson regression that accommodates over-dispersion. Akaike's Information Criterion and Residual Moran's *I* were again calculated to assess residual spatial variation and goodness of fit.

Table E.5. Exponentiated betas for negative binomial univariate analysis by census block group (n=653)

Variable	**β**	**Univariate (RR)**	**p-value**
Alcohol outlet count	0.191	1.211	<0.001
Population (per 1,000 residents)	0.144	1.159	0.171
Population density (per square mile in 1,000 residents)	-0.015	0.985	0.0122
Percent of all lots that are vacant (%)	0.020	1.020	<0.001
Median household income (in $1,000s)	-0.008	0.992	<0.001
Mean daily traffic volume (in 1,000 vehicles)	0.040	1.041	<0.001
Schools	0.101	1.107	0.244
Physical disorder	0.044	1.045	0.144
Social activity	-0.0156	0.985	0.893
Roadway infrastructure	-0.116	0.890	0.713
Intersection infrastructure	0.161	1.174	<0.001
Distance from downtown	-0.233	0.792	<0.001

Table E.6. Exponentiated betas and fit statistics for negative binomial multivariate analysis by census block group

Model	Variables	β_1		β_2		β_3		β_4		β_5		β_6		Residual Moran's *I*		AIC
		RR	**p**	**RR**	**p**	**RR**	**p**	**RR**	**p**	**RR**	**p**	**RR**	**p**	***I***	**p**	
Null	Injury count													0.215	<0.001	
1	1. Alcohol	1.211	<0.001											0.036	0.042	1967
2	1. Alcohol 2. PopTotal	1.212	<0.001	0.958	0.683									0.036	0.043	1963
3	1. Alcohol 2. AreaPop	1.207	<0.001	0.992	0.141									0.041	0.023	1967
4	1. Alcohol 2. AreaPop 3. Vacant%	1.200	<0.001	0.988	0.040	1.025	<0.001							0.034	0.053	1947
4a	1. Alcohol 2. AreaPop 3. Vacant% 4. AreaPop* Vacant%	1.200	<0.001	0.989	0.110	1.026	0.013	1.000	0.890					0.033	0.054	1949
5	1. Alcohol 2. AreaPop 3. Vacant% 4. Income	1.205	<0.001	0.988	0.040	1.017	0.002	0.991	<0.001					0.019	0.168	1934
6§	1. Alcohol 2. AreaPop 3. Vacant% 4. Income 5. Schools	1.203	<0.001	0.990	0.074	1.018	<0.001	0.992	<0.001	1.160	0.055			0.018	0.180	1933
7	1. Alcohol 2. AreaPop 3. Vacant% 4. Income 5. Phys.Disorder	1.205	<0.001	0.988	0.039	1.016	0.020	0.991	<0.001	1.005	0.884			0.019	0.162	1936

Table E.6. Negative binomial modeling (cont.)

Model	Variables	β_1		β_2		β_3		β_4		β_5		β_6		Residual Moran's *I*		AIC
		RR	p	RR	p	RR	p	RR	p	RR	p	RR	p	*I*	p	
8	1. Alcohol 2. AreaPop 3. Vacant% 4. Income 5. SocialActivity	1.202	<0.001	0.989	0.052	1.019	0.002	0.991	<0.001	0.908	0.435			0.019	0.173	1936
9	1. Alcohol 2. AreaPop 3. Vacant% 4. Income 5. Roadway	1.204	<0.001	0.988	0.038	1.017	0.002	0.991	<0.001	0.961	0.891			0.019	0.163	1936
10	1. Alcohol 2. AreaPop 3. Vacant% 4. Income 5. Traffic	1.200	<0.001	0.989	0.053	1.020	<0.001	0.992	<0.001	1.034	<0.001			0.004	0.405	1927
11	1. Alcohol 2. AreaPop 3. Vacant% 4. Income 5. TrafficLag	1.193	<0.001	0.989	0.054	1.023	<0.001	0.991	<0.001	1.091	<0.001			-0.002	0.509	1915
11a	1. Alcohol 2. Vacant% 3. Income 4. TrafficLag	1.197	<0.001	1.022	<0.001	0.991	<0.001	1.093	<0.001					-0.008	0.617	1917

Table E.6. Negative binomial modeling (cont.)

Model	Variables	β1		β2		β3		β4		β5		β6		Residual Moran's *I*		AIC
		RR	p	RR	p	RR	p	RR	p	RR	p	RR	p	*I*	p	
12†	1. Alcohol 2. AreaPop 3. Vacant% 4. Income 5. TrafficLag 6. Distance	1.162	<0.001	0.984	0.005	1.017	0.003	0.992	<0.001	1.084	<0.001	0.887	0.002	0.011	0.275	1906
13‡	1. Alcohol 2. AreaPop 3. Vacant% 4. Income 5. TrafficLag 6. Intersection	1.176	<0.001	0.986	0.013	1.020	<0.001	0.992	<0.001	1.086	<0.001	1.068	0.002	0.0122	0.263	1911

§Correlation between AreaPop and Schools: r=-0.166, p<0.0001

†Correlation between Alcohol and Distance from downtown: r=-0.295, p<0.0001

‡Correlation between Alcohol and Intersection score: r=0.21, p<0.0001

SECTION III. SENSITIVITY ANALYSIS

Table E.7. Exponentiated betas and fit statistics for negative binomial multivariate sensitivity analysis by census block group

		β_1		β_2		β_3		β_4		β_5		β_6		Residual Moran's *I*		
Model	**Variables**	**RR**	**p**	**RR**	**p**	**RR**	**p**	**RR**	**p**	**RR**	**p**	**RR**	**p**	***I***	**p**	**AIC**
Replaced alcohol outlets with distance from downtown																
14	1. Distance 2. AreaPop 3. Vacant% 4. Income 5. TrafficLag	0.797	<0.001	0.974	<0.001	1.014	0.019	0.994	0.005	1.099	<0.001			0.085	<0.001	1957
14a	1. Distance 2. Vacant% 3. Income 4. TrafficLag	0.830	<0.001	1.014	0.029	0.994	0.006	1.109	<0.001					0.090	<0.001	1974
Replaced alcohol outlets with intersection score																
15	1. Intersection 2. AreaPop 3. Vacant% 4. Income 5. TrafficLag	1.145	<0.001	0.978	<0.001	1.019	0.003	0.995	0.025	1.106	<0.001			0.116	<0.001	1974
15a	1. Intersection 2. Vacant% 3. Income 4. TrafficLag	1.118	<0.001	1.017	0.006	0.995	0.025	1.116	<0.001					0.116	<0.001	1987
Removed outlier block group with 32 alcohol outlets and 40 injuries (n=652)																
16	1. Alcohol 2. AreaPop 3. Vacant% 4. Income 5. TrafficLag	1.225	<0.001	0.989	0.055	1.022	<0.001	0.991	<0.001	1.092	<0.001			0.065	0.001	1901

Table E.7. Sensitivity analysis (cont.)

Model	Variables	β_1		β_2		β_3		β_4		β_5		β_6		Residual Moran's *I*		AIC
		RR	p	RR	p	RR	p	RR	p	RR	p	RR	p	*I*	p	
Removed outlier block group with 32 alcohol outlets and 40 injuries (n=652)																
16a	1. Alcohol 2. Vacant% 3. Income 4. TrafficLag	1.230	<0.001	1.021	<0.001	0.991	<0.001	1.094	<0.001					0.059	0.003	1903
17	1. Distance 2. AreaPop 3. Vacant% 4. Income 5. TrafficLag	0.829	<0.001	0.978	<0.001	1.016	0.007	0.993	0.002	1.088	<0.001			0.059	0.002	1932
18	1. Intersection 2. AreaPop 3. Vacant% 4. Income 5. TrafficLag	1.117	<0.001	0.991	0.002	1.019	0.001	0.994	0.008	1.091	<0.001			0.082	<0.001	1943
Removed block groups with missing data—13 missing median household income and/or population count (n=640)																
19	1. Alcohol 2. AreaPop 3. Vacant% 4. Income 5. TrafficLag	1.189	<0.001	0.989	0.065	1.023	<0.001	0.992	<0.001	1.093	<0.001			0.002	0.431	1867
19a	1. Alcohol 2. Vacant% 3. Income 4. TrafficLag	1.192	<0.001	1.023	<0.001	0.992	<0.001	1.096	<0.001					-0.002	0.513	1868

Table E.7. Sensitivity analysis (cont.)

Model	Variables	β_1		β_2		β_3		β_4		β_5		β_6		Residual Moran's *I*		AIC
		RR	**p**	**RR**	**p**	**RR**	**p**	**RR**	**p**	**RR**	**p**	**RR**	**p**	***I***	**p**	
Removed block groups with missing data and outlier block group (n=639)																
20	1. Alcohol 2. AreaPop 3. Vacant% 4. Income 5. TrafficLag	1.220	<0.001	0.989	0.065	1.023	<0.001	0.992	<0.001	1.094	<0.001			0.075	<0.001	1854
20a	1. Alcohol 2. Vacant% 3. Income 4. TrafficLag	1.224	<0.001	1.022	<0.001	0.992	<0.001	1.096	<0.001					0.070	<0.001	1855

APPENDIX F. DISCUSSION OF ZERO-INFLATED REGRESSION

Often in injury prevention studies, the dependent variable of interest consists of count data with an excessive number of zeros—in other words, the data contain more zeros than are expected under a Poisson or negative binomial distribution given the sample mean (Lord et al., 2007). In these instances, the application of zero-inflated regression models has become increasingly popular (Lambert, 1992; Lord et al., 2005, 2007).

The zero-inflated model assumes the excessive zeros in the dependent variable result from two states which could be assumed to exist simultaneously. In one of the states, the zero-injury state, all units of interest (e.g., intersections, census block groups, study participants) can be regarded as fundamentally safe or reporting zero injuries (Chin & Quddus, 2003). The other state is the non-zero-injury state, in which the frequency of injuries is assumed to follow some known distribution such as the Poisson or negative binomial distribution (Chin & Quddus, 2003).

In the current study, 46.1% (n=301) of census block groups reported zero pedestrian injuries. While this may constitute an excessive number of zeros, there is some debate over the application of zero-inflated models to transportation injury studies. Lord and colleagues (2005, 2007) argue that crash data characterized by a preponderance of zeros is not caused by a dual-state process (the mixture of truly safe with unsafe sites) as an inherently safe roadway does not exist. Rather, roadways should be referred to in relative terms, as being more or less safe compared to another roadway (Lord et al., 2007). Furthermore, studies comparing the application of different modeling schemes suggested that there was little difference in fit between negative binomial and zero-inflated negative binomial models, and recommended the use of negative binomial models in preference to zero-inflated models in the interest of parsimony (Khan et al., 2011; Ullah et al., 2010).

In the current study, when deciding whether to implement a zero-inflated negative binomial model (ZINB) versus a standard negative binomial model (NB), we calculated the AIC-corrected Vuong statistic (Lord et al., 2007; Vuong, 1989). The Vuong statistic for ZINB vs. NB models was 0.82 (p=0.2), indicating that the NB and ZINB models were indistinguishable (Peng et al., 2014; Vuong, 1989). We also modeled the zero-accident probability state for pedestrian injury count with all of our predictor variables (e.g., schools, intersection safety score, physical disorder score, etc.) and found no significant predictors of the zero-accident probability state. The parameter estimates and standard errors for the NB model and the ZINB non-zero accident probability state (Table F.1) are similar.

Table F.1. Parameter estimates and standard errors for NB and ZINB models (n=653)

Variable	**NB Adjusted*** **(RR)**	**SE**	**p-value**	**ZINB Adjusted*** **(RR)**	**SE**	**p-value**
Alcohol outlet count	1.193	0.019	<0.001	1.141	0.024	<0.001
Population density (per square mile in 1,000 residents)	0.989	0.005	0.054	0.983	0.006	0.005
Percent of all lots that are vacant (%)	1.023	0.005	<0.001	1.016	0.006	0.005
Median household income (in $1,000s)	0.991	0.002	<0.001	0.991	0.002	<0.001
Lagged traffic volume	1.091	0.018	<0.001	1.087	0.023	<0.001

*adjusted for other covariates in the column

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APPENDIX G. INVENTORY FOR PEDESTRIAN SAFETY INFRASTRUCTURE DATA FORM

Rater Initials: ________________ LID: _____________________ Store Name: ____

Block Segment 1:

Roadway Features						
1	One-way or two-way street	One-way (0)		Two-way (1)		
2	Number of street lanes	Count: __________				
3	Posted Speed Limit	Yes (1)		No (0)		
4	Speed limit, if you can read it:	Limit: __________				
5	Street lights or lampposts	Yes (1)		No (0)		
6	On-street parking (parallel or diagonal/back-in parking)	None (0)	Parallel only (1)	Diagonal only (2)	Both (3)	
7	Presence of alley streets	Yes (1)		No (0)		
8	Presence of driveways	Yes (1)		No (0)		
9	Sidewalk on one or both sides of street?	None (0)	1 side only (1)	Both (2)		
10	Sidewalk maintenance and walkability	Good (0)	Fair (1)	Poor (2)		
11	Traffic island or median	Yes (1)		No (0)		
12	Speed bumps or humps	Yes (1)		No (0)		
13	Pedestrian overpass, underpass, or bridge	Yes (1)		No (0)		
14	Fence or other barrier to prevent street crossing	Yes (1)		No (0)		
15	Bus stops	Yes (1)		No (0)		
16	Highway on- or exit-ramp	Yes (1)		No (0)		
Midblock Features						
17	Number of marked mid-block crosswalks	Count: __________				
18	Number of crosswalks with reflectors or flashing lights	Count: __________				
19	Number of pedestrian crossing signs	Count: __________				
20	Number of pedestrian crossing signals	Count: __________				

Block Segment 2 (corner stores **only**):

Roadway Features					
21	One-way or two-way street	One-way (0)	Two-way (1)		
22	Number of street lanes	Count: __________			
23	Posted Speed Limit	Yes (1)	No (0)		
24	Speed limit, if you can read it:	Limit: _______________			
25	Street lights or lampposts	Yes (1)	No (0)		
26	On-street parking (parallel or diagonal/back-in parking)	None (0)	Parallel only (1)	Diagonal only (2)	Both (3)
27	Presence of alley streets	Yes (1)	No (0)		
28	Presence of driveways	Yes (1)	No (0)		
29	Sidewalk on 1 or both sides of street?	None (0)	1 side only (1)	Both (2)	
30	Sidewalk maintenance and walkability	Good (0)	Fair (1)	Poor (2)	
31	Traffic island or median	Yes (1)	No (0)		
32	Speed bumps or humps	Yes (1)	No (0)		
33	Pedestrian overpass, underpass, or bridge	Yes (1)	No (0)		
34	Fence or other barrier to prevent street crossing	Yes (1)	No (0)		
35	Bus stops	Yes (1)	No (0)		
36	Highway on- or exit-ramp	Yes (1)	No (0)		
Midblock Features					
37	Number of marked mid-block crosswalks	Count: ______			
38	Number of crosswalks with reflectors or flashing lights	Count: ______			
39	Number of pedestrian crossing signs	Count: ______			
40	Number of pedestrian crossing signals	Count: ______			

Name of Cross Streets of Intersection:

Number of streets at intersection:

Intersection Features			
41	Traffic circle or roundabout	Yes (1)	No (0)
42	Number of intersecting street segments	Count: _________	
43	Number of marked crosswalks at an intersection at the site of a walk signal, stop light or stop sign	Count: _________	
44	Number of marked crosswalks at intersection NOT associated with walk signal, stop light or stop sign	Count: _________	
45	Number of crosswalks with reflectors or flashing lights	Count: _________	
46	Number of streets with traffic lights	Count: _________	
47	Number of stop signs	Count: _________	
48	Number of yield signs	Count: _________	
49	Number of pedestrian crossing signals	Count: _________	
50	Number of pedestrian crossing signs	Count: _________	
51	Number of streets with stop line set back from crosswalk	Count: _________	

APPENDIX H. INVENTORY FOR PEDESTRIAN SAFETY INFRASTRUCTURE FIELD GUIDE

Inventory for Pedestrian Safety Infrastructure Protocol

For a liquor store located on a corner, you will consider the street block segments on the blocks immediately surrounding the liquor store. A street block segment is the distance from one intersection to the next intersection, a distance of approximately 0.1 miles.

For this protocol, we will use the example of Cardinal Tavern, located at 901 S Clinton Street.

You will make notes on the pedestrian safety measures that are present at the intersection and block segments <u>immediately next to</u> the liquor store. You will <u>not</u> take measures of the intersection that is farthest from the alcohol outlet.

Write down the cross streets of the intersection (S Clinton Street and Hudson Street) and the block number for each block segment (900 block of S Clinton Street; 3300 block of Hudson Street).

Start at the corner in front of the alcohol outlet. Walk or drive down one side of the first block segment (3300 block of Hudson Street). Take notes on the **Roadway Features** of this block. For example, does the block have street lights? Is it a one-way or two-way street? Do <u>not</u> record any measures for the intersection at the far end of the block (in this case, the intersection of Hudson Street and Highland Ave). It may take you several times walking up and down the block segment to record all of the **Roadway Features**. Make sure to be as thorough as possible when judging if the items on your list are present on the block.

Once you have finished recording all the measures under **Roadway Features**, you should judge the **Midblock Features**. These are specific items that address the safety of crossing the street anywhere other than at the intersection. For example, if you stood at 3311 Hudson Street and you wanted to cross the street to get to 3312 Hudson Street, are there any crosswalks or other things in the middle of the block that would make it safe for you to cross the street?

Once you have finished recording all of the **Roadway Features** and **Midblock Features**, return to the corner in front of the alcohol outlet. You will now assess the **Intersection Features** of the cross-streets located directly in front of the alcohol outlet (in this case, the intersection of S Clinton Street and Hudson Street). Write down the number of streets that are intersecting (in this case, 2 streets are intersecting). Write down the number of stop signs, cross walks, and other items on the list that you can see from standing at the corner in front of the liquor store. You don't need to cross the street to finish this list.

Once you have finished the **Intersection Features**, you will repeat the **Roadway Features** and **Midblock Features** items, but this time you will complete the measures for the second block segment (in this case, the 900 block of S Clinton Street)

When you are finished, you should have a list of measures for 1 intersection and 2 block segments, or 5 sets of measures: 2 sets of **Roadway Features**, 2 sets of **Midblock Features**, and 1 set of **Intersection Features**.

For an alcohol outlet located midblock, you will assess the street block segments on the block immediately surrounding the alcohol outlet, as well as the intersection at the end of the block that is closest to the liquor store. A street block segment is the distance from one intersection to the next intersection, a distance of approximately 0.1 miles.

For this protocol, we will use the example of M&L Canton Discount Liquors, located at 2923 O'Donnell Street in Canton.

You will make notes on the pedestrian safety measures that are present at intersection closest to the liquor store and the block segment immediately next to the liquor store. It is up to you to decide what the closest intersection is. You will not take measures of the other block segments connected to the intersections.

Write down the block number (2900 block of O'Donnell Street) and the cross streets of the nearest intersection (S Curley Street and O'Donnell Street). It is up to you to decide what the nearest intersection is.

Start on the side of the block in front of the alcohol outlet. Walk down this block (2900 block of O'Donnell Street). Take notes on the **Roadway Features** of this block. For example, does the block have street lights? Is it a one-way or two-way street? It may take you several times walking up and down the block to record all of the **Roadway Features**. Make sure to be as thorough as possible in judging if the features on your list are present on the block.

Once you have finished recording all the measures under **Roadway Features**, you should assess the **Midblock Features**. These are specific items that address the safety of crossing the street anywhere other than at the intersection. For example, if you stood at M & L Discount Liquors and you wanted to cross the street directly in front of this alcohol outlet, are there any crosswalks or other infrastructure in the middle of the block that would make your crossing safer?

Once you have finished recording all of the **Roadway Features** and **Midblock Features**, stand at the corner of the intersection closest to the liquor store (S Curley Street and O'Donnell Street). You will now judge the **Intersection Features**. Write down the number of streets that are intersecting (in this case, 2 streets are intersecting). Record the number of stop signs, cross walks, and other items on the list that you can see from standing at the corner. You do not need to cross the street to finish this list. Do <u>not</u> write down any items for the intersection at the other end of the block (in this case, the intersection of O'Donnell Street and S Potomac Street).

When you are finished, you should have measures for 1 intersection and 1 block segment, or 3 sets of measures: 1 set of **Roadway Features**, 1 set of **Midblock Features**, and 1 set of **Intersection Features**.

Appendix of Measures

Roadway Features

- One-way or two-way street

- Number of street lanes (total number of lanes, regardless of direction)

- Posted Speed Limit
    - If speed limit can be read, please record it.

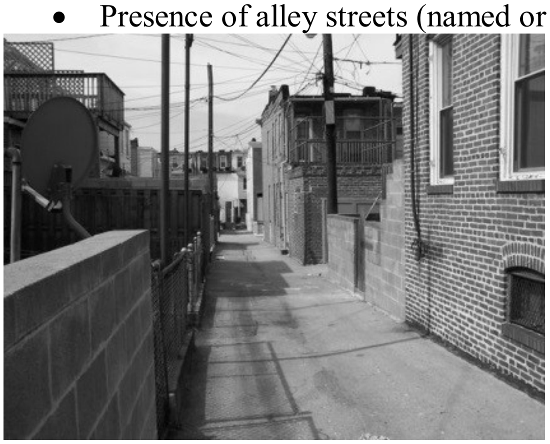
- Street lights or lampposts

- On-street parking (parallel or diagonal parking)

Parallel parking

Diagonal, back-in parking

- Presence of alley streets (named or unnamed street)

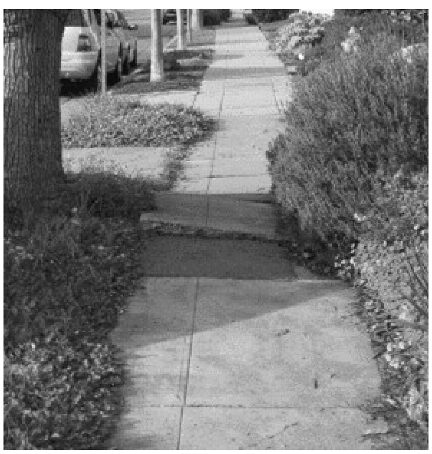


- Presence of driveways

- Sidewalks—Is the sidewalk complete on one or both sides of the street?
    - No sidewalk present=0; sidewalk on one side only=1; sidewalk on both sides=2

- Sidewalk condition and walkability. What is the condition of the maintenance of the sidewalk?
    - Good (0)=Sidewalk is in pristine or near pristine condition, very easy to traverse

    - Fair (1)=Sidewalk has some unevenness and obstacles but can still be navigated;



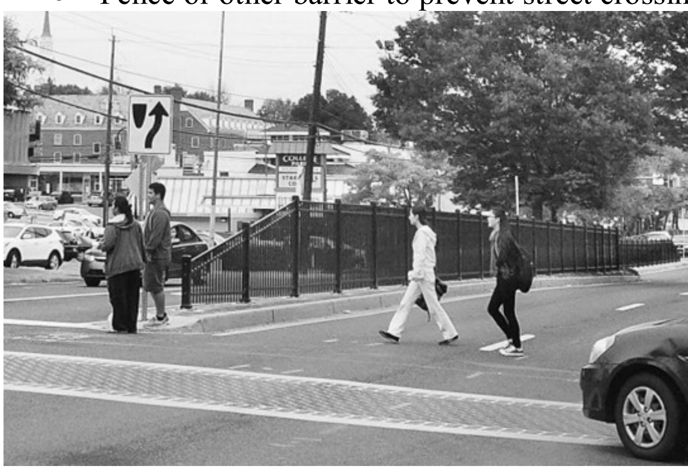
- Poor (3)=Sidewalk is extremely difficult or nearly impossible to traverse


- Traffic island or median


- Speed bumps or humps


- Pedestrian overpass, underpass, or bridge

- Fence or other barrier to prevent street crossing

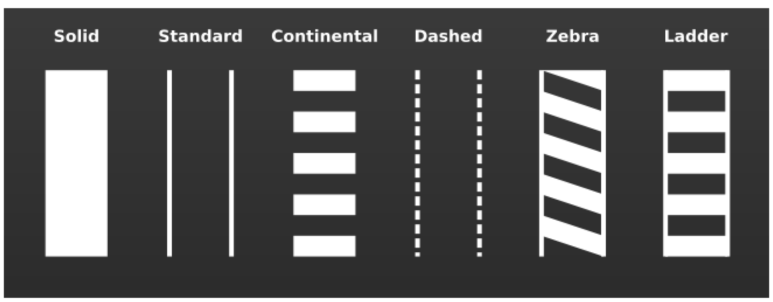


- Bus stops
- Highway on-ramp or exit-ramp

Intersection Features

- Traffic circle or roundabout

- Marked crosswalks (includes white painted lines, colored painted lines or zebra striping) at an intersection at the site of a pedestrian walk signal, stop light or stop sign



Possible markings for marked crosswalks

Crosswalk at the site of a pedestrian-activated walk signal

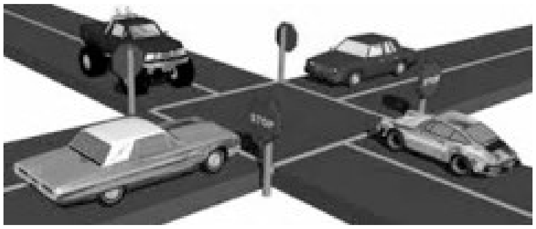
- Marked crosswalks (includes white painted lines, colored painted lines or zebra striping) at intersection <u>NOT</u> associated with pedestrian walk signal, stop light or stop sign

- Reflectors or flashing lights embedded in pavement to mark crosswalk

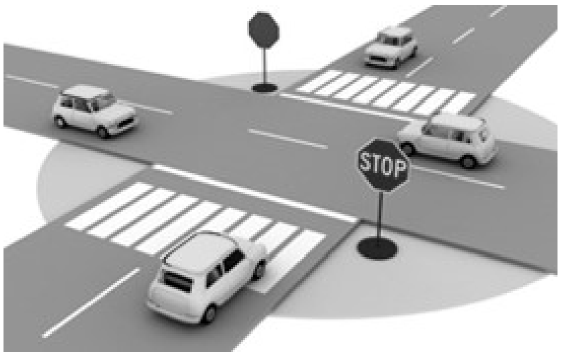
- Traffic control signals (traffic signal, traffic light or stop light)

- Stop sign

4-way and All-way stop sign
(Stop signs are red)



4 stop signs
(Stop signs placed at every corner of intersection)



Stop signs at 2 sides of intersection only

- Yield sign

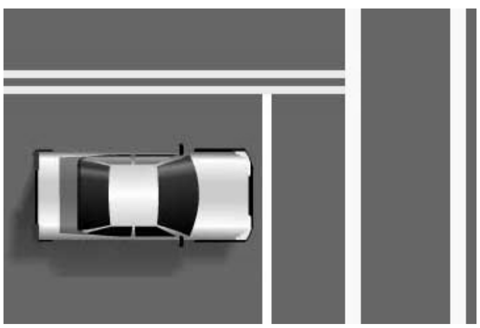
Yield signs are red or, in rare cases, yellow.

- Pedestrian crossing signal

- Pedestrian crossing sign

Pedestrian crossing signs are yellow

- Stop line set back from cross-walk at intersection



Midblock Features

- Marked mid-block crosswalks (delineated with white painted lines, colored painted lines or zebra striping)
- Reflectors or flashing lights embedded in pavement to mark crosswalk
- Pedestrian crossing sign
- Pedestrian crossing signal

APPENDIX I. INVENTORY FOR PEDESTRIAN SAFETY INFRASTRUCTURE TRAINING PRESENTATION

Pedestrian Safety Infrastructure Inventory Training

Elizabeth Nesoff, MPH
July 7, 2015

Slide 1

Why pedestrian injury?

- Baltimore has the 10th highest rate of pedestrian fatalities compared to 51 other cities
  - From 2003-2012, 482 pedestrian fatalities in Baltimore
  - 20% of all traffic-related fatalities were among pedestrians
- Alcohol use is one of the main risk factors for pedestrian injury
  - In 2012, alcohol was involved in 48% of crashes that resulted in pedestrian fatalities. Of the pedestrians, 34% were drunk, while only 14% of drivers were drunk

2

Slide 2

Alcohol is an important risk factor for pedestrian injury

- Intoxication increases risk of being both the perpetrator and victim of pedestrian injury
  - Pedestrians who are drunk are more likely to cross the street unsafely
  - Drunk pedestrians experience more severe injuries compared to sober pedestrians
- More pedestrian injuries occur in areas of greater alcohol outlet density

3

Slide 3

For liquor stores on the corner….

Slide 4

For the first block segment…

- Write down the cross streets of the intersection and the block number for each block segment
- Walk or drive down one side of the first block segment Take notes on the **Roadway Features** of this block.
- Do <u>not</u> record any measures for the intersection at the far end of the block
- It may take you several times walking up and down the block segment to record all of the **Roadway Features**. Make sure to be as thorough as possible when judging if the items on your list are present on the block.
- Once you have finished recording all the measures under **Roadway Features**, you should judge the **Midblock Features**. These are specific items that address the safety of crossing the street <u>anywhere other than at the intersection</u>.

Slide5

First block segment

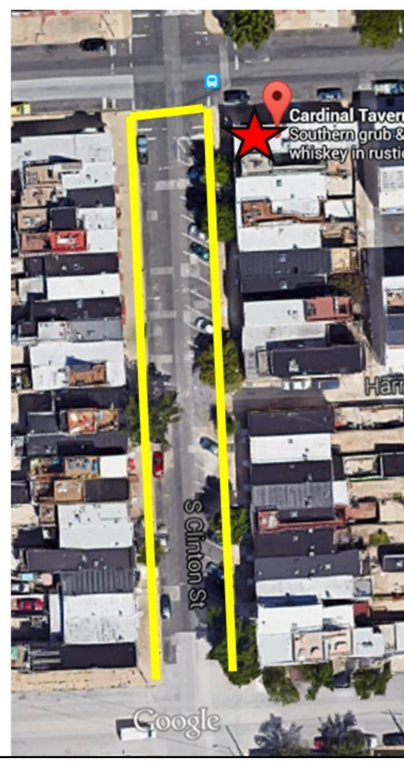
Slide 6

Once you've finished the Roadway Features and Midblock Features…

- You will now assess the **Intersection Features** of the cross-streets located directly in front of the alcohol outlet
- Write down the number of streets that are intersecting (in this case, 2 streets are intersecting)
- Write down what you can see from standing at the corner in front of the liquor store
- You don't need to cross the street to finish the list

Slide 7

After you finish the **Intersection Features**, repeat the **Roadway Features** and **Midblock Features**, but this time you will complete the measures for the second block segment



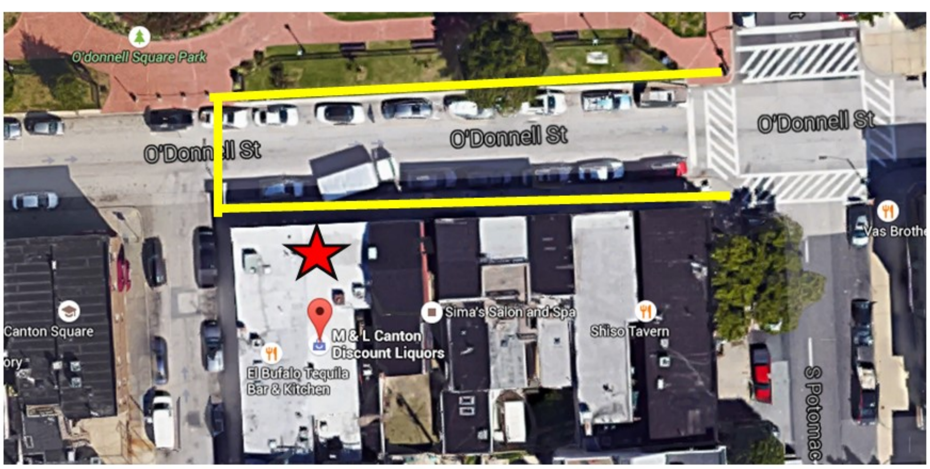
Slide 8

For liquor stores located mid-block…

- Assess the street block segments on the block immediately surrounding the alcohol outlet, as well as the intersection at the end of the block that is <u>closest</u> to the liquor store.
- Write down the block number and the cross streets of the <u>nearest</u> intersection (It is up to you to decide what the nearest intersection is).
- Roadway Features, Midblock Features, and Intersection Features

Slide 9

Only 1 block and 1 intersection for liquor stores located midblock



Slide 10

Roadway Features

- One-way or two-way street
- Number of street lanes (total number of lanes, regardless of direction)
- Posted Speed Limit
  - If speed limit can be read, please record it.

- Street lights or lampposts

Slide 11

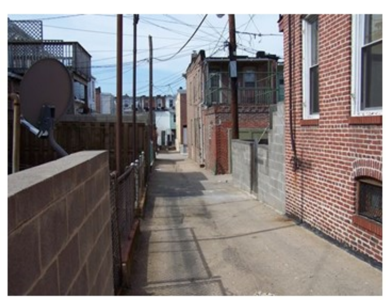
Roadway Features

- On-street parking

Parallel Parking

Diagonal Parking

- Presence of alleys



Slide 12

Roadway Features

- Presence of driveways
- Bus stops
- Highway on-ramp or exit-ramp
- Sidewalks
  - No sidewalk
  - sidewalk on one side of the street only
  - sidewalk on both sides of the street

Slide 13

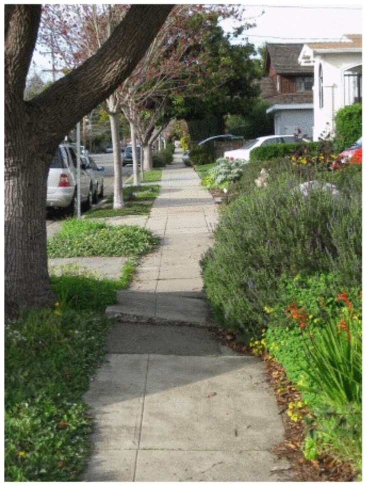
Roadway Features

- Sidewalk condition and walkability. What is the condition of the maintenance of the sidewalk?
  - Good=Sidewalk is in pristine or near pristine condition, very easy to walk across

Slide 14

Roadway Features: Sidewalk Condition

Fair=Sidewalk has some unevenness and obstacles but can still be navigated



Slide 15

Roadway Features: Sidewalk Condition

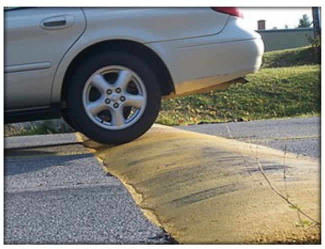
Poor=Sidewalk is extremely difficult or nearly impossible to traverse

Slide 16

Roadway Features

- Traffic island or median

- Speed bumps or humps



Slide 17

Roadway Features

- Pedestrian overpass, underpass, or bridge

- Fence or other barrier to prevent street crossing

Slide 18

Intersection Features

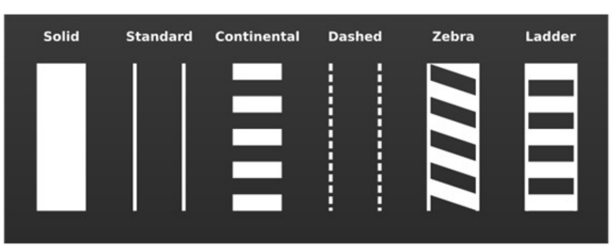
- Traffic circle or roundabout

Slide 19

Intersection Features

- Marked crosswalks at an intersection at the site of a pedestrian walk signal, stop light or stop sign

Crosswalk at the site of a pedestrian-activated walk signal



Possible markings for marked crosswalks

Slide 20

Intersection Features

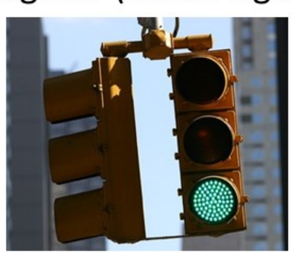
- Marked crosswalks at intersection NOT associated with pedestrian walk signal, stop light or stop sign

Slide 21

Intersection Features

- Reflectors or flashing lights embedded in pavement to mark crosswalk

- Traffic control signals (traffic signal, traffic light or stop light)

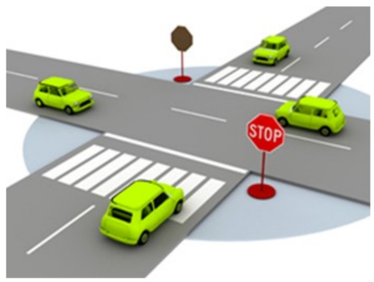


Slide 22

Intersection Features

- Number of Stop Signs

4 stop signs
(Stop signs placed at every corner of intersection)



Stop signs at 2 sides of intersection only

Slide 23

Intersection Features

- Yield Sign

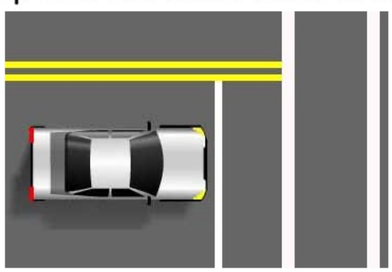
- Pedestrian Crossing Signal

Slide 24

Intersection Features

- Pedestrian Crossing Sign

- Stop line set back from cross-walk at intersection



Slide 25

Midblock Features

- Marked mid-block crosswalks (delineated with white painted lines, colored painted lines or zebra striping)
- Reflectors or flashing lights embedded in pavement to mark crosswalk
- Pedestrian crossing sign
- Pedestrian crossing signal

Slide 26

APPENDIX J. SUMMARY OF EXPLORATORY FACTOR ANALYSIS FOR IPSI ROADWAY AND INTERSECTION SCALES

SECTION I. Correlation matrices for IPSI measures

```
. pwcorr  IStreetNum ICrossWSign ICrossNoSign IStreetTrafLight IStopSign IYieldSign IPedCrossSignal IPedCrossSign IStreetSto
> pLine, sig
```

	IStree~m	IC~WSign	IC~oSign	IStree~t	IStopS~n	IYield~n	IPedCr~l
IStreetNum	1.0000						
ICrossWSign	0.0676	1.0000					
	0.3795						
ICrossNoSign	-0.0821	-0.2377	1.0000				
	0.2856	0.0017					
IStreetTra~t	0.0909	0.7370	-0.3500	1.0000			
	0.2369	0.0000	0.0000				
IStopSign	-0.0266	-0.2851	0.1717	-0.6747	1.0000		
	0.7300	0.0002	0.0247	0.0000			
IYieldSign	-0.0181	-0.0988	0.3541	-0.0770	-0.0515	1.0000	
	0.8145	0.1987	0.0000	0.3166	0.5034		
IPedCrossS~l	0.1625	0.7135	-0.3363	0.8839	-0.6484	-0.0740	1.0000
	0.0338	0.0000	0.0000	0.0000	0.0000	0.3359	
IPedCrossS~n	0.1887	0.1803	0.2472	0.1164	-0.0968	0.2220	0.1428
	0.0135	0.0183	0.0011	0.1294	0.2077	0.0035	0.0625
IStreetSto~e	0.0932	0.8994	-0.2404	0.7480	-0.2365	-0.0912	0.6593
	0.2256	0.0000	0.0015	0.0000	0.0018	0.2354	0.0000

	IPedCr~n	IStree~e
IPedCrossS~n	1.0000	
IStreetSto~e	0.1591	1.0000
	0.0376	

```
. pwcorr  IStreetNum ICrossWSign ICrossNoSign IStreetTrafLight IStopSign IYieldSign IPedCrossSignal IPedCrossSign IStreetSto
> pLine, sig print (0.05)
```

	IStree~m	IC~WSign	IC~oSign	IStree~t	IStopS~n	IYield~n	IPedCr~l
IStreetNum	1.0000						
ICrossWSign		1.0000					
ICrossNoSign		-0.2377	1.0000				
		0.0017					
IStreetTra~t		0.7370	-0.3500	1.0000			
		0.0000	0.0000				
IStopSign		-0.2851	0.1717	-0.6747	1.0000		
		0.0002	0.0247	0.0000			
IYieldSign			0.3541			1.0000	
			0.0000				
IPedCrossS~l	0.1625	0.7135	-0.3363	0.8839	-0.6484		1.0000
	0.0338	0.0000	0.0000	0.0000	0.0000		
IPedCrossS~n	0.1887	0.1803	0.2472			0.2220	
	0.0135	0.0183	0.0011			0.0035	
IStreetSto~e		0.8994	-0.2404	0.7480	-0.2365		0.6593
		0.0000	0.0015	0.0000	0.0018		0.0000

	IPedCr~n	IStree~e
IPedCrossS~n	1.0000	
IStreetSto~e	0.1591	1.0000
	0.0376	

```
. tetrachoric R_Way R_PostSpeed R_Alley R_Driveway R_BusStop StopLine_bin CrossWSign_bin CrossNoSign_bin TrafLight_bin StopS
> ign_bin YieldSign_bin PedCrossSignal_bin PedCrossSign_bin, star(0.05)
(obs=171)

matrix with tetrachoric correlations is not positive semidefinite;
  it has 3 negative eigenvalues
  maxdiff(corr,adj-corr) =  0.7442
  (adj-corr: tetrachoric correlations adjusted to be positive semidefinite)

             |    R_Way R_Post~d  R_Alley R_Driv~y R_BusS~p StopLi~n CrossW~n CrossN~n TrafLi~n StopSi~n YieldS~n Pe~l_bin
-------------+------------------------------------------------------------------------------------------------------------
       R_Way |   1.0000 
 R_PostSpeed |   0.2404   1.0000 
     R_Alley |  -0.1699   0.2515   1.0000 
  R_Driveway |   0.1967   0.2296   0.0612   1.0000 
   R_BusStop |   0.2828*  0.0937   0.0003   0.4867*  1.0000 
StopLine_bin |  -0.1022   0.2404   0.2645*  0.1175   0.4188*  1.0000 
CrossWSign~n |  -0.0584   0.3091*  0.2701*  0.1434   0.3842*  0.9913*  1.0000 
CrossNoSig~n |  -0.0307   0.1661   0.1140  -0.1707  -0.3612  -0.0307   0.1784   1.0000 
TrafLight_~n |   0.0419   0.1243   0.1393   0.3042*  0.6403*  0.8998*  0.9067* -1.0000*  1.0000 
StopSign_bin |  -0.1272  -0.0622  -0.0992  -0.4412* -0.6706* -0.7488* -0.7408*  0.6596* -1.0000*  1.0000 
YieldSign_~n |   1.0000  -1.0000  -1.0000   1.0000   1.0000  -1.0000  -1.0000   1.0000  -1.0000  -1.0000   1.0000 
PedCro~l_bin |   0.1321   0.1389   0.0468   0.3162*  0.6849*  0.8752*  0.8848* -1.0000*  1.0000* -1.0000* -1.0000   1.0000 
PedCro~n_bin |   0.1486   0.1904  -0.0109   0.2140   0.0110   0.3530*  0.4816*  0.4436*  0.1836  -0.2752   1.0000   0.1185 

             | Pe~n_bin
-------------+---------
PedCro~n_bin |   1.0000 
```

Key
2-sided exact P

```
matrix with tetrachoric correlations is not positive semidefinite;
  it has 3 negative eigenvalues
  maxdiff(corr,adj-corr) =  0.7442
  (adj-corr: tetrachoric correlations adjusted to be positive semidefinite)
```

	R_Way	R_Post~d	R_Alley	R_Driv~y	R_BusS~p	StopLi~n	CrossW~n	CrossN~n	TrafLi~n	StopSi~n	YieldS~n	Pe~l_bin
R_Way												
R_PostSpeed	0.1022											
R_Alley	0.1797	0.0679										
R_Driveway	0.1469	0.0851	0.6316									
R_BusStop	0.0393	0.4700	1.0000	0.0001								
StopLine_bin	0.4996	0.1022	0.0435	0.4208	0.0019							
CrossWSign~n	0.7328	0.0282	0.0410	0.2590	0.0051	0.0000						
CrossNoSig~n	0.8153	0.3073	0.4761	0.3610	0.0509	0.8153	0.3383					
TrafLight_~n	0.7499	0.3894	0.3319	0.0140	0.0000	0.0000	0.0000	0.0000				
StopSign_bin	0.3311	0.7276	0.5133	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000			
YieldSign_~n	1.0000	1.0000	1.0000	0.4737	0.3275	0.3450	0.3275	0.1287	0.4737	1.0000		
PedCro~l_bin	0.3352	0.3046	0.7482	0.0093	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	
PedCro~n_bin	0.3998	0.2559	1.0000	0.1594	1.0000	0.0331	0.0026	0.0049	0.2300	0.0686	0.1754	0.4279

	Pe~n_bin
PedCro~n_bin	

```
. polychoric ICrossWSign IStreetTrafLight IPedCrossSignal IStreetStopLine R_Lanes R_PostSpeed R_BusStop R_Par
> k R_Driveway R_Alley R_SidewClean
```

Polychoric correlation matrix

	ICrossWSign	IStreetTrafLight	IPedCrossSignal	IStreetStopLine	R_Lanes
ICrossWSign	1				
IStreetTrafLight	.80048655	1			
IPedCrossSignal	.74795431	.89659084	1		
IStreetStopLine	.9194886	.8599745	.68649536	1	
R_Lanes	.30156968	.40440022	.45907903	.2565085	1
R_PostSpeed	.25448866	.12020277	.21891931	.20049838	.24243226
R_BusStop	.46915695	.57443284	.63701033	.37693163	.67014769
R_Park	.11199775	-.07863727	-.17225345	.14142142	-.47960246
R_Driveway	.24097635	.2138923	.35100724	.09071726	.5261656
R_Alley	.20586778	.01203654	.10047319	.03976795	-.23141378
R_SidewClean	-.15732319	-.09339087	-.18337122	-.02709986	-.3005495

	R_PostSpeed	R_BusStop	R_Park	R_Driveway	R_Alley
R_PostSpeed	1				
R_BusStop	.10668261	1			
R_Park	-.15567975	-.54144162	1		
R_Driveway	.21604839	.49455246	-.28929934	1	
R_Alley	.23404957	.01004357	.20877923	.0477819	1
R_SidewClean	.05718331	-.15363481	-.03104821	-.03726104	.2637452

	R_SidewClean
R_SidewClean	1

```
. matrix r=r(R)
```

SECTION II. Exploratory factor analysis with principal component extraction and verimax rotation

```
. factormat r, n(170) factors(3) pcf
(obs=170)

Factor analysis/correlation                        Number of obs    =      170
    Method: principal-component factors           Retained factors =        3
    Rotation: (unrotated)                          Number of params =       30
```

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	4.42960	2.40568	0.4027	0.4027
Factor2	2.02391	0.63177	0.1840	0.5867
Factor3	1.39214	0.47275	0.1266	0.7132
Factor4	0.91938	0.14417	0.0836	0.7968
Factor5	0.77521	0.16042	0.0705	0.8673
Factor6	0.61480	0.29171	0.0559	0.9232
Factor7	0.32309	0.06204	0.0294	0.9526
Factor8	0.26105	0.08478	0.0237	0.9763
Factor9	0.17627	0.10583	0.0160	0.9923
Factor10	0.07044	0.05632	0.0064	0.9987
Factor11	0.01412	.	0.0013	1.0000

```
LR test: independent vs. saturated:  chi2(55) = 1559.48 Prob>chi2 = 0.0000
```

Factor loadings (pattern matrix) and unique variances

Variable	Factor1	Factor2	Factor3	Uniqueness
ICrossWSign	0.8407	0.4453	-0.0390	0.0933
IStreetTra~t	0.8911	0.2726	-0.1545	0.1078
IPedCrossS~l	0.9025	0.1280	-0.0363	0.1678
IStreetSto~e	0.7865	0.5032	-0.1378	0.1091
R_Lanes	0.6607	-0.5738	-0.0520	0.2315
R_PostSpeed	0.3107	-0.0047	0.5804	0.5666
R_BusStop	0.7796	-0.3926	0.0646	0.2340
R_Park	-0.2721	0.7590	-0.1972	0.3110
R_Driveway	0.4869	-0.4367	0.3284	0.4643
R_Alley	0.0426	0.4362	0.6842	0.3398
R_SidewClean	-0.2045	0.2028	0.6227	0.5293

```
. rotate,  blanks(.35)

Factor analysis/correlation                        Number of obs    =      170
    Method: principal-component factors            Retained factors =        3
    Rotation: orthogonal varimax (Kaiser off)      Number of params =       30
```

Factor	Variance	Difference	Proportion	Cumulative
Factor1	3.78626	1.17704	0.3442	0.3442
Factor2	2.60921	1.15904	0.2372	0.5814
Factor3	1.45018	.	0.1318	0.7132

```
    LR test: independent vs. saturated:  chi2(55) = 1559.48 Prob>chi2 = 0.0000

Rotated factor loadings (pattern matrix) and unique variances
```

Variable	Factor1	Factor2	Factor3	Uniqueness
ICrossWSign	0.9447			0.0933
IStreetTra~t	0.9233			0.1078
IPedCrossS~l	0.8439			0.1678
IStreetSto~e	0.9422			0.1091
R_Lanes		0.7952		0.2315
R_PostSpeed			0.5551	0.5666
R_BusStop	0.4700	0.7367		0.2340
R_Park		-0.8125		0.3110
R_Driveway		0.6909		0.4643
R_Alley			0.7845	0.3398
R_SidewClean			0.6527	0.5293

```
    (blanks represent abs(loading)<.35)
```

Factor rotation matrix

	Factor1	Factor2	Factor3
Factor1	0.8600	0.5102	0.0106
Factor2	0.4837	-0.8214	0.3022
Factor3	-0.1629	0.2548	0.9532

```
. estat common
```

Correlation matrix of the varimax rotated common factors

Factors	Factor1	Factor2	Factor3
Factor1	1		
Factor2	0	1	
Factor3	0	0	1

SECTION III. Estimation of Cronbach's Alpha for final IPSI scales

Intersection Scale

Item	Obs	Sign	item-test correlation	item-rest correlation	average interitem covariance	alpha
ICrossWSign	171	+	0.8693	0.7988	1.429848	0.7058
IStreetTra~t	171	+	0.9333	0.8972	1.362303	0.6871
IPedCrossS~l	171	+	0.9466	0.8337	.7990188	0.7801
IStreetSto~e	171	+	0.8423	0.7722	1.558328	0.7217
R_Park	170	-	0.1086	0.0473	2.450537	0.8264
R_BusStop	171	+	0.4764	0.4326	2.305561	0.8081
Test scale					1.651245	0.7929

Item	Obs	Sign	item-test correlation	item-rest correlation	average interitem covariance	alpha
ICrossWSign	171	+	0.8788	0.8124	2.328196	0.7498
IStreetTra~t	171	+	0.9333	0.8969	2.240787	0.7331
IPedCrossS~l	171	+	0.9436	0.8244	1.334985	0.8425
IStreetSto~e	171	+	0.8530	0.7867	2.540179	0.7670
R_BusStop	171	+	0.4628	0.4182	3.808537	0.8630
Test scale					2.450537	0.8264

Item	Obs	Sign	item-test correlation	item-rest correlation	average interitem covariance	alpha
ICrossWSign	171	+	0.8842	0.8184	4.188728	0.8081
IStreetTra~t	171	+	0.9332	0.8956	4.044112	0.7902
IPedCrossS~l	171	+	0.9416	0.8121	2.400596	0.9188
IStreetSto~e	171	+	0.8582	0.7920	4.600711	0.8299
Test scale					3.808537	0.8630

Roadway Scale

```
. alpha R_Lanes R_BusStop R_Driveway R_Park, item

Test scale = mean(unstandardized items)
```

Item	Obs	Sign	item-test correlation	item-rest correlation	average interitem covariance	alpha
R_Lanes	171	+	0.8995	0.5475	.0615622	0.4928
R_BusStop	171	+	0.6557	0.4880	.1638639	0.4705
R_Driveway	171	+	0.6009	0.4100	.183539	0.5124
R_Park	170	-	0.5449	0.3223	.2011352	0.5494
Test scale					.1525726	0.5808

Possible third scale, rejected for lack of internal consistency

Item	Obs	Sign	item-test correlation	item-rest correlation	average interitem covariance	alpha
R_PostSpeed	171	+	0.5522	0.1188	.050258	0.2950
R_Alley	171	+	0.6587	0.2274	.0118679	0.0823
R_SidewClean	171	+	0.7124	0.1494	.0317509	0.2609
Test scale					.0312923	0.2914

CURRICULUM VITAE

Elizabeth Dora Nesoff

CONTACT

Johns Hopkins Bloomberg School of Public Health
Department of Health, Behavior and Society
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Baltimore, MD 21205
enesoff1@jhu.edu

BIOGRAPHICAL SKETCH

Elizabeth D. Nesoff, MPH, CHES, was born in November 29, 1983, in Bronx, NY, USA. She holds an MPH from the Emory University Rollins School of Public Health and a BA from Wellesley College. Prior to undertaking her doctoral studies, Elizabeth worked at the Centers for Disease Control and Prevention as a research fellow with the Division for Heart Disease and Stroke Prevention and later as a health communication fellow with the National Center for HIV/AIDS, Viral Hepatitis, STD and TB Prevention. She has extensive experience in health disparities research, as well as practical experience in research translation, health promotion, and program planning. Her dissertation research focuses on the impact of the alcohol environment on pedestrian injury risk. She was awarded a Ruth L. Kirschstein National Research Service Award from the National Institute on Alcohol Abuse and Alcoholism in September 2015 in support of her dissertation research. She was also awarded several institutional grants in support of her research from the Johns Hopkins Center for Injury Research & Policy, the Delta Omega Society Alpha Chapter, and the Johns Hopkins Office of Public Health Practice & Training. She passed her written comprehensive exam with honors in June 2013, her preliminary oral exams in January 2015, and her final oral exam in April 2017. Elizabeth is in the process of publishing several manuscripts related to the neighborhood alcohol environment, pedestrian injury, and injury prevention communication.

EDUCATION

The Johns Hopkins University Bloomberg School of Public Health Baltimore, MD
Doctor of Philosophy, Department of Health, Behavior and Society Expected May 2017
Dissertation: "The Neighborhood Alcohol Environment & Pedestrian Injury Risk: A Spatial Analysis of Pedestrian Injury in Baltimore City"

Emory University Rollins School of Public Health Atlanta, GA
Master of Public Health, Department of Behavioral Science and Health Education May 2010

Wellesley College Wellesley, MA
Bachelor of Arts**,** *magna cum laude*, French and Women's Studies June 2005

RESEARCH EXPERIENCE

NIH Ruth L. Kirschstein National Research Service Award Pre-doctoral Fellow Sep 2015 – Present
Johns Hopkins University Bloomberg School of Public Health, Baltimore, MD
Advisor: Dr. Debra Furr-Holden

- Provided intensive training, mentoring, and research opportunities in alcohol and substance abuse epidemiology, spatial analysis, and environmental observation

Graduate Research Assistant July 2013 – Present
Pedestrian Safety Workgroup, Center for Injury Research and Policy
Johns Hopkins University Bloomberg School of Public Health, Baltimore, MD
Advisor: Dr. Andrea Gielen

- Coordinated data collection and analysis for health promotion campaign evaluation project. Activities included creation of a novel analysis tool, training and supervising undergraduates in analysis of video recordings of driver and pedestrian behavior, video recording of high-risk intersections in East Baltimore
- Assisted in creation, implementation and evaluation of evidence-based health promotion media campaign to promote safe pedestrian and driving behaviors

ORISE Research Fellow Sep 2011 – Aug 2012
Health Communication Science Office, National Center for HIV/AIDS, Viral Hepatitis, STD & TB Prevention
Centers for Disease Control and Prevention, Atlanta, GA

- Created evidence-based health communication content for health websites, including LGB and transgender health
- Analyzed national survey data on acceptability of various web platforms for health messaging delivery
- Assisted in development of social determinants health messaging language for scientific and consumer publications

ORISE Research Fellow Aug 2010 – Aug 2011
Applied Research and Translation Team, Division for Heart Disease and Stroke Prevention
Centers for Disease Control and Prevention, Atlanta, GA

- Assisted in survey item development and preparation of U.S. Office of Management and Budget (OMB) approval package documents for survey on management of heart disease risk factors in primary care settings
- Performed qualitative data analysis to assess barriers to heart attack emergency care among rural Native Americans
- Translated science into practice through the creation of evidence-based tools and publications

Interviewer Jan – May 2010
Georgia Medical Monitoring Project, HIV Epidemiology Unit
Georgia Department of Community Health, Division of Public Health, Atlanta, GA

- Interviewed HIV patients on access to health care and support services as part of national surveillance project
- Researched and performed data analysis to assess access to HIV care services' impact on health outcomes

Association of Schools of Public Health (ASPH) Intern June – Dec 2009
Capacity Building Branch, Division of HIV/AIDS Prevention
Centers for Disease Control and Prevention, *Atlanta, GA*

- Developed and analyzed survey of Native American community organizations' needs and barriers to implementing HIV prevention interventions
- Assisted in the creation of HIV prevention intervention for African American adolescent girls by coordinating focus groups, editing intervention materials, and coordinating facilitator training

Research Assistant Sep 2008 – Dec 2009
Emory University Rollins School of Public Health, Atlanta, GA
Advisor: Dr. Kristin Dunkle

- Performed qualitative analysis for study of health care practitioners who work with HIV-positive men in South Africa
- Assisted in creation of national telephone survey on effects of gender and race on sexual decision-making and HIV risk among African American women

GRANT HISTORY

Ruth L. Kirschstein Pre-doctoral National Research Service Award Sep 2015 – Present
National Institute on Alcohol Abuse and Alcoholism, National Institutes of Health
"Alcohol and Pedestrian Injury: Inquiry into Built and Social Environment Factors" (F31AA023716)

PEER-REVIEWED PUBLICATIONS

1. **Nesoff, ED**, Milam, AJ, Bone, L.…, Furr-Holden, CDM. (2016) Tobacco Policies and On-Premise Smoking in Bars and Clubs that Cater to Young African Americans following the Maryland Clean Indoor Air Act of 2007. *Journal of Ethnicity in Substance Abuse*, 12, 1-16 [Epub ahead of print]

2. **Nesoff, ED**, Brownstein, JN, Veazie, M. et al. (2017). Time-to-Treatment for Myocardial Infarction: Barriers and Facilitators Perceived by American Indians in Three Regions. *Journal of Community Health, 42*(1): 129-138.

3. Furr-Holden, CDM, Milam, AJ, **Nesoff, ED**, et al. (2016). Triangulating Syndemic Services and Drug Treatment Policy: Improving Drug Treatment Portal Locations in Baltimore City. *Progress in Community Health Partnerships, 10*(2): 319-27.

4. Milam, AJ, Johnson, RM, **Nesoff, ED**, Furr-Holden, CDM. (2016). Evaluating Nighttime Observational Measures of Neighborhood Disorder: Validity of the Nighttime NIfETy Assessment. *Journal of Environmental Psychology, 45*, 97-102.

5. Furr-Holden, CDM, Milam, AJ, **Nesoff, ED**, et al. (2016). Not in My Back Yard: A Comparative Analysis of Crime around Publicly-funded Drug Treatment Centers, Liquor Stores, Convenience Stores, and Corner Stores in one Mid-Atlantic City. *Journal of Studies on Alcohol and Drugs, 77*(1), 17-24.

6. **Nesoff, ED**, Dunkle, K, Lang, D. (2016). The impact of condom use negotiation self-efficacy and partnership patterns on consistent condom use among college-educated women. *Health Education & Behavior*, *43*(1), 61-67.

Articles under review:

1. Furr-Holden, CDM, Milam, AJ, **Nesoff, ED**, Thorpe, R. (In revision). Understanding the Relationship between Alcohol Outlet Density and Average Life Expectancy in Baltimore City. *American Journal of Community Psychology*.

2. **Nesoff, ED**, McDonald, EM, Bailey, M., Pollack, KM, Gielen, A. (In review). Unsafe Street Crossing Behavior by Adults: Can the Theory of Planned Behavior Help? *Accident Analysis & Prevention*

3. Pollack, KM, **Nesoff, ED**, Bailey, M, Gielen, A. (In review). Knowledge and Attitudes Regarding Pedestrian Safety: Differences between Drivers and Pedestrians and Implications for Prevention. *Preventing Chronic Disease*.

4. Bailey M, McDonald E, Williams J,…**Nesoff ED**, Gielen A. (In review). Creating an Evidence-Informed Pedestrian Safety Communication Campaign for a High-Risk Urban Area. *Journal of Community Health.*

CONFERENCE PRESENTATIONS

1. **Nesoff, E**. "The Neighborhood Alcohol Environment & Injury: A Spatial Analysis of Pedestrian Injury in Baltimore City." Research Society on Alcoholism 39th Annual Scientific Meeting. June 28, 2016. New Orleans, LA.

2. **Nesoff, E**. "Novel Methods for Environmental Assessment of Pedestrian Injury: Creation & Validation of Inventory for Pedestrian Safety Infrastructure." Society for Prevention Research 24th Annual Meeting. June 1, 2016. San Francisco, CA.

3. **Nesoff, E**. "Alcohol Outlets and Pedestrian Injury in Baltimore City: A Spatial Analysis" (poster). Alcohol Policy Conference 17. April 7, 2016. Washington, D.C.

4. **Nesoff, E**. "Alcohol Outlets and Pedestrian Injury in Baltimore City: A Spatial Analysis" (poster). Society of Public Health Educators 66th Annual Meeting. April 24, 2015. Portland, OR.

5. **Nesoff, E**., Brownstein, J.N., Brody, E., et al. "MI Time-to-Treatment in rural American Indian country: Qualitative insight into delays." American Public Health Association 140th Annual Meeting. October 30, 2012. San Francisco, CA.

HONORS AND AWARDS

NIAAA Alcohol Policy Scholarship (travel award to the Alcohol Policy 17 conference) 2016
National Institute on Alcohol Abuse and Alcoholism (NIAAA) at the National Institutes of Health (NIH)

Susan P. Baker Scholarship in Injury Prevention & Control (dissertation research award) 2015 – 2016
Center for Injury Research & Policy, Johns Hopkins Bloomberg School of Public Health

Drug Dependence Epidemiology Training Fellowship (training and research award) 2015
National Institute on Drug Abuse (NIDA) at the National Institutes of Health (NIH)

Delta Omega Society Applied Research Scholarship Award (dissertation research award) 2015
Alpha Chapter, Public Health Honor Society, Johns Hopkins Bloomberg School of Public Health

Health Resources & Services Administration Trainee Fellowship (training and research award) 2015
Office of Public Health Practice & Training, Johns Hopkins Bloomberg School of Public Health

SOPHE/CDC Student Fellowship in Injury Prevention (research award) 2014 – 2015
Society for Public Health Educators (SOPHE)

Wellesley College Alumnae Graduate Fellowship 2014 – 2015
Wellesley College

Charles C. Shepard Award finalist (awarded to most scholarly research thesis) 2010
Emory University Rollins School of Public Health

Sallie B. Lee Scholarship (half tuition and research assistantship grant) 2008 – 2010
Emory University Rollins School of Public Health

Magna Cum Laude 2005
Wellesley College

First Year Academic Distinction 2002
Wellesley College

TEACHING EXPERIENCE

Johns Hopkins University Bloomberg School of Public Health
Baltimore, MD
Head Teaching Assistant to Dr. Andrea Gielen, Dept. of Health, Behavior &Society Sep 2013 – Oct 2015
- Assisted in instruction for fall and spring sessions of "Program Planning for Health Behavior Change" by facilitating class discussion and grading individual and group assignments. Enrollment: 96

Head Teaching Assistant to Dr. Larry Cheskin, Dept. of Health, Behavior & Society January – May 2015
- Led instruction for three class sessions, created all assignments and exams, led lesson planning, and graded individual assignments for "Clinical & Public Health Behavior Change" undergraduate course. Enrollment: 110

Teaching Assistant to Drs. Peter Winch & Julie Denison, Dept. of International Health Oct – Dec 2013
- Led instruction for five class sessions and graded individual assignments for "Health Behavior Change at the Individual, Household and Community Levels." Enrollment: 105

Emory University Rollins School of Public Health
Atlanta, GA
Head Teaching Assistant to Dr. Cynthia Jorgensen, Dept. of Behavioral Science & Health Ed. Fall 2009
- Assisted in instruction for "Theory in Behavioral Science and Health Education" by facilitating class discussion and grading individual and group assignments. Enrollment: 36

PROFESSIONAL ASSOCIATIONS

American Public Health Association (APHA)
Research Society on Alcoholism (RSoA)
Society for Prevention Research (SPR)
Society for Public Health Educators (SOPHE)

OTHER PROFESSIONAL ACTIVITIES

Certifications: Certified Health Education Specialist (CHES), National Commission for Health Education Credentialing
Journal Peer Review: *AIDS Care*

LEADERSHIP & VOLUNTEER ACTIVITIES

Wellesley College Alumnae Association, *Class of 2005 President* June 2015 – Present
Health, Behavior & Society Student Organization Co-President, JHU June 2013 – June 2014
Gay Men's Health Crisis, New York, NY. (*HIV support as meals program volunteer*) Aug – Dec 2006
Planned Parenthood of Hudson-Peconic, NY. (*Performed internal staff audits*) Sep – Dec 2005

COMMUNICATIONS EXPERIENCE

Springer Science + Business Media, New York, NY (*Edi Assist., Health & Behavior)* Jan 2006 – Jan 2007
The Atlantic Monthly, Boston, MA (*Editorial Intern)* Sep – Dec 2004
The New York Sun, New York, NY (*News Desk Intern)* May – Aug 2004
The Christian Science Monitor, New York, NY (*Intern*) May – Aug 2003
- Featured on NPR's Boston affiliate WBUR's "OnPoint" and WRKO-AM's morning show with Peter Blute to discuss opinion piece, "In Search of Feminists"

The Wellesley News, Wellesley, MA (*Managing Editor*) Sep 2001 – Dec 2003